Technical Memorandum:

Delta Risk Management Strategy (DRMS) Phase 1

Topical Area:

Flood Hazard

Draft 2

Prepared by:
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Prepared for:
California Department of Water Resources (DWR)

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URS

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Subject: **Delta Risk Management Strategy**
Phase 1 Draft 2 Technical Memorandum –Flood Hazard

Dear Mr. Svetich,

Please find herewith a copy of the subject technical memorandum. Members of the Steering Committee's Technical Advisory Committee and agency staff have reviewed the draft technical memorandum, and this second draft addresses their comments.

This document was prepared by Dr. Thomas MacDonald, Senior Hydrologist (URS), and Mr. Phil Mineart, Senior Hydrologist (URS). Internal peer review was provided in accordance with URS' quality assurance program, as outlined in the (DRMS) project management plan.

Sincerely,

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Preamble

The Delta Risk Management Strategy (DRMS) project was authorized by DWR to perform a risk analysis of the Delta and Suisun Marsh (Phase 1) and to develop a set of improvement strategies to manage those risks (Phase 2) in response to Assembly Bill 1200 (Laird, Chaptered, September 2005). The Technical Memorandum (TM), is one of 12 TMs (2 topics are presented in one TM: hydrodynamics and water management) prepared for topical areas for Phase 1 of the DRMS project. The topical areas covered in the Phase 1 Risk Analysis include:

1. Geomorphology of the Delta and Suisun Marsh
2. Subsidence of the Delta and Suisun Marsh
3. Seismic Hazards of the Delta and Suisun Marsh
4. Global Warming Effects in the Delta and Suisun Marsh
5. Flood Hazard of the Delta and Suisun Marsh
6. Wind Wave Action of the Delta and Suisun Marsh
7. Levee Vulnerability of the Delta and Suisun Marsh
8. Emergency Response and Repair of the Delta and Suisun Marsh Levees
9. Hydrodynamics of the Delta and Suisun Marsh
10. Water Management and Operation of the Delta and Suisun Marsh
11. Ecological Impacts of the Delta and Suisun Marsh
12. Impact to Infrastructure of the Delta and Suisun Marsh
13. Economic Impacts of the Delta and Suisun Marsh

Note that the Hydrodynamics and Water Quality topical area was combined with the Water Management and Operations topical area because they needed to be considered together in developing the model of levee breach water impacts for the risk analysis. The resulting team is the Water Analysis Module (WAM) Team and this TM is the Water Analysis Module TM.

The work product described in these TMs will be used to develop the integrated risk analysis of the Delta and Suisun Marsh. The results of the integrated risk analysis will be presented in a technical report referred to as:

14. Risk Analysis – Report

The first draft of this report was made available to the DRMS Steering Committee in April 2007.

Assembly Bill 1200 amends Section 139.2 of the Water Code, to read, “The department shall evaluate the potential impacts on water supplies derived from the Sacramento-San Joaquin Delta based on 50-, 100-, and 200-year projections for each of the following possible impacts on the delta:

1. Subsidence.
2. Earthquakes.
3. Floods.
4. Changes in precipitation, temperature, and ocean levels.
5. A combination of the impacts specified in paragraphs (1) to (4) inclusive.”

In addition, Section 139.4 was amended to read: (a) The Department and the Department of Fish and Game shall determine the principal options for the delta. (b) The Department shall evaluate and comparatively rate each option determined in subdivision (a) for its ability to do the following:

1. Prevent the disruption of water supplies derived from the Sacramento-San Joaquin Delta.
2. Improve the quality of drinking water supplies derived from the delta.
3. Reduce the amount of salts contained in delta water and delivered to, and often retained in, our agricultural areas.
4. Maintain Delta water quality for Delta users.
5. Assist in preserving Delta lands.
6. Protect water rights of the “area of origin” and protect the environments of the Sacramento- San Joaquin river systems.
7. Protect highways, utility facilities, and other infrastructure located within the delta.
8. Preserve, protect, and improve Delta levees.…”

In meeting the requirements of AB 1200, the DRMS project is divided into two parts. Phase 1 involves the development and implementation of a risk analysis to evaluate the impacts to the Delta of various stressing events. In Phase 2 of the project, risk reduction and risk management strategies for long-term management of the Delta will be developed.

Definitions and Assumptions

During the Phase 1 study, the DRMS project team developed various predictive models of future stressing events and their consequences. These events and their consequences have been estimated using engineering and scientific tools readily available or based on a broad and current consensus among practitioners. Such events include the likely occurrence of future earthquakes of varying magnitude in the region, future rates of subsidence given continued farming practices, the likely magnitude and frequency of storm events, the potential effects of global warming (sea level rise, climate change, and temperature change) and their effects on the environment. Using the current state of knowledge, estimates of the likelihood of these events occurring can be made for the 50-, 100-, and 200-year projections with some confidence.

While estimating the likelihood of stressing events can generally be done using current technologies, estimating the consequences of these stressing events at future times is somewhat more difficult. Obviously, over the next 50, 100, and 200 years, the Delta will undergo changes that will affect what impact the stressing events will have. To assess those consequences, some assumptions about the future “look” of the Delta must be established.

To address the challenge of predicting impacts under changing conditions, DRMS adopted the approach of evaluating impacts absent changes in the Delta as a baseline.

This approach is referred to as the “business-as-usual” (BAU) scenario. Defining a business-as-usual Delta is required, since one of the objectives of this work is to estimate whether ‘business-as-usual’ is sustainable for the foreseeable future. Obviously changes from this baseline condition can occur; however, as a basis of comparison for risks and risk reduction measures, the BAU scenario serves as a consistent standard rather than as a “prediction of the future” and relies on existing agreements, policies, and practices to the extent possible.

In some cases, there are instances where procedures and policies may not exist to define standard emergency response procedure during a major (unprecedented) stressing event in the Delta or restoration guidelines after such a major event. In these cases, prioritization of action will be based on: (1) existing and expected future response resources, and (2) highest value recovery/restoration given available resources.

This study relies solely on available data. Because of the limited time to complete this work, no investigation or research were to be conducted to supplement the state of knowledge.

Perspective

The analysis results presented in this technical memorandum do not represent the full estimate of risk for the topic presented herein. The subject and results are expressed whenever possible in probabilistic terms to characterize the uncertainties and the random nature of the parameters that control the subject under consideration. The results are the expression of either the probable outcome of the hazards (earthquake, floods, climate change, subsidence, wind waves, and sunny day failures) or the conditional probability of the subject outcome (levee failures, emergency response, water management, hydrodynamic response of the Delta and Suisun Marsh, ecosystem response, and economic impacts) given the stressing events.

A full characterization of risk is presented in the Risk Analysis Report. In that report, the integration of the probable initiating events, the conditional probable response of the Delta levee system, and the expected probable consequences are integrated in the risk analysis module to develop a complete assessment of risk to the Delta and Suisun Marsh.

Consequently, the subject areas of the technical memoranda should be viewed as pieces contributing to the total risk, and their outcomes represent the input to the risk analysis module.

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Acronyms and Abbreviations

CDEC	California Data Exchange Center
cfs	cubic feet per second
CSMR	Cosumnes River
Delta	Sacramento–San Joaquin River Delta
DRMS	Delta Risk Management Strategy
DWR	Department of Water Resources
LPIII	Log Pearson Type III
misc	miscellaneous streams

Moke	Mokelumne River
NOAA	National Oceanic and Atmospheric Administration
PMF	Probable Maximum Flood
Sac	Sacramento River
SJR	San Joaquin River
TDI	Total Delta Inflow
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
WY	Water Year
Yolo	Yolo Bypass

1. Introduction

1.1 Background

Damages in the Sacramento–San Joaquin River Delta (Delta) could result from earthquakes, floods, subsidence, animal burrowing activity, and other natural events. Extreme hydrologic events could result in major damages throughout the Delta. Knowledge of the magnitude, characteristics, and probability of various hydrologic events is needed as input into development of a Delta Risk Management Strategy (DRMS).

1.2 Purpose

One failure mechanism that will be analyzed in the Risk Analysis Model is levee failure due to a hydrologic event. For each hydrologic event the information needed includes the probability of the event, an estimate of the uncertainty associated with that probability and the water surface elevation (stage) at various locations within the Delta associated with that event. As is described in Section 2 of this memorandum an event is defined by the magnitude of the total inflow to the Delta. Since the stage in the Delta is a function of not only the total inflow into the Delta but also the distribution of the inflow between the different inflow sources it is necessary to distribute the total Delta inflow between the different inflow sources. Associated with each distribution of inflows is the probability associated with that inflow distribution, which is an output of these analyses. Additionally, the probability of a given tide concurrent with the inflow event and inflow distribution is a factor effecting water surface elevations and risks and is also an output of these analyses.

The purpose of the analyses presented in this technical memorandum is to develop methods for estimating hydrologic characteristics in the Delta that are needed as input to the Risk Analysis, such as inflow magnitudes and patterns, tides, and the probabilities and uncertainties of occurrence and the associated water surface elevations. The method used in the Risk Analysis requires a large number of simulations (thousands or millions) so the methods used to generate the hydrologic inputs to the Risk Analysis need to be simple and robust.

1.3 Scope

Data and analyses used for estimating water surface elevations in the Delta are addressed in the following sections:

- Section 2 – Hydrologic Data
- Section 3 – Flow-Frequency Analyses
- Section 4 – Delta Inflow Patterns
- Section 5 – Delta Water Surface Elevations
- Section 6 – Future Hydraulic Risks

- Section 7 – Summary
- Section 8 – References

2. Hydrologic Data

2.1 Tide Data

Tides, as well as magnitudes and patterns of inflow, will influence water surface elevations in the Delta and therefore must be considered. Tide data used in these analyses are water surface elevation measurements at the San Francisco tide station (National Oceanic and Atmospheric Administration [NOAA] station 9414290). For purposes of these analyses, the water surface elevation measurements at the San Francisco station are referred to as tides and include astronomical tides, storm surges, and other factors influencing the water surface elevation. The San Francisco tide station was chosen for its long record of unbroken tide data dating back about 150 years. Tide levels at this station are relatively independent of inflows into the Delta while providing a geographically relevant measure of tailwater conditions that influence water levels in the Delta.

2.2 Delta Inflow and River Stage Data

Average daily total Delta inflow, in cubic feet per second (cfs), is the parameter used to define a hydrologic event in the Delta. Average daily inflows into the Delta are available from the California Department of Water Resources (DWR) website for the 50 water years (WYs) from October 1, 1955, through September 30, 2005 (WY 1956 through WY 2005). These data include average daily inflows for all major streams entering the Delta and the total inflow into the Delta (DWR 2006). The major streams or stream groups included in the dataset are Sacramento River, Yolo Bypass, Cosumnes River, Mokelumne River, San Joaquin River, and miscellaneous streams. Flows in miscellaneous streams are primarily Calaveras River flows. The locations of flow measuring stations used in the analysis are shown in Figure 2-1. Measured average daily inflows into the Delta are summarized graphically on Figure 2-2. Figure 2-2a presents total inflows into the Delta for the period of record. Figure 2-2b presents inflows from Sacramento River and Yolo Bypass, the major contributors to total inflow (>80 percent). Figure 2-2c presents inflows from San Joaquin River, the second-largest contributor to total inflow (>10 percent).

Water surface elevations in the Delta were estimated from data on historic water levels measured at selected Delta gauging stations. Water levels, or stages, at the selected gauging stations were then used to interpolate stages at intermediate locations in the Delta. The California Data Exchange Center (CDEC) provides information on an extensive hydrologic data collection network, including automatic river stage sensors in the Delta. River stage data are provided primarily from the stations maintained by the DWR and USGS. The stage data can be downloaded from the CDEC website (CDEC, no date; http://cdec.water.ca.gov/queryCSV.html.). A detailed discussion of the stage data is given in Section 5 of this Technical Memorandum.

2.3 Probable Maximum Flood Inflow Data

For the DRMS studies, inflow-frequency analyses of measured annual peak total daily inflows were used to provide estimates of peak inflows that could occur under extreme hydrologic conditions. However, the inflow-frequency estimates are based on statistical analyses of a limited number of years of data and do not recognize that an upper limit to the severity of hydrologic events is controlled by meteorological conditions of the area. For purposes of these studies, the upper limit of inflow into the Delta was assumed to be an extreme event comparable in magnitude to the inflow resulting from a Probable Maximum Precipitation event over the Delta and tributary area, i.e., the Probable Maximum Flood (PMF) inflow into the Delta.

PMF data that were used in these studies were obtained from the U.S. Bureau of Reclamation (USBR; USBR 1986). USBR identified 61 historical extreme flood events that occurred throughout the United States and had estimated maximum runoff rates. PMF analyses were made for the watersheds associated with the historic flood events to determine if their PMF analysis methodology gives results that are consistent with historical data. These studies demonstrated that their methodology did give consistent and realistic estimates of PMF runoff. These analyses also provide data needed in the DRMS studies to estimate an upper limit of Delta inflows that that could occur.

In addition to these USBR PMF data, estimates of PMF peak runoff were obtained from the USBR website for five dams that are located in Northern California and/or tributary to the Delta: Trinity, New Melones, Friant, Folsom, and Shasta (USBR, no date; http://www.usbr.gov/dataweb/dams/).

The PMF estimates used in these studies are summarized in Table 2-1.

2.4 Analyses of Hydrologic Data

One of the objectives of these studies is to develop estimates of hydrologic characteristics of the Delta under current conditions in the tributary watersheds. Thus, it was necessary to examine the available Delta inflow data to determine if these data adequately reflect current watershed conditions or if the statistical characteristics of the data have significantly changed during the period of recorded data due to new reservoirs in the watersheds, developments in the watershed, land use changes, and other factors.

As shown on Figure 2-2, the period from about 1987 to 1993 had relatively fewer large flood inflow events than before 1987. This 6-year period had below-average precipitation and is the longest period of below-average rainfall between 1955 and 2005. This suggests that during the 50-year period of record, more drought years occurred in the recent period of record than in earlier years. It is therefore desirable to use the entire period of available inflow record to avoid or reduce any statistical bias caused by the recent drought years.

Several dams and reservoirs, developments, and other changes have been constructed in the watersheds tributary to the Delta and the impacts of these changes could have affected inflows into the Delta. Table 2-2 is a partial list of dams and reservoirs that have been constructed in the tributary watersheds. As shown in Table 2-2, the reservoirs behind Oroville and New Melones dams are two of the largest reservoirs constructed during the period of available inflow measurements. Analyses were made to determine if Oroville

Dam and other watershed changes since construction of the dam had a significant impact on Delta inflows from Sacramento River and Yolo Bypass. Similar analyses were made with regard to San Joaquin River since construction of New Melones Dam.

Table 2-3 summarizes the measured Delta inflows for three periods. For the Sacramento watershed, the periods are the pre-Oroville Dam period (1956–1968), the post-Oroville Dam period (1969–2005), and the entire period of record. For the San Joaquin River watershed, the periods are the pre- and post-New Melones Dam periods (1956–1979 and 1980–2005, respectively), and the entire period of record. Since no major storage projects have been developed on the Delta tributaries since construction of New Melones Dam, the post-New Melones Dam period is considered to represent current conditions. As shown in Table 2-3, the average number of days per year with high inflows (>10,000 cfs) from San Joaquin River is greater during current conditions in the watershed than before New Melones Dam was constructed and the average number of days per year of low inflows (<10,000 cfs) is less. This situation is contrary to what would be expected if New Melones Dam and reservoir were reducing large flow events. Similarly, Table 2-3 shows more high (>100,000 cfs) and fewer low (<100,000 cfs) total inflows from the Sacramento River watershed since the construction of Oroville Dam.

Table 2-4 lists, in descending order, the maximum daily total Delta inflow for each WY of the period of record. Examination of the flood inflow dates presented in Table 2-4 shows that four out of the five largest inflow days and seven out of the 12 largest inflow days occurred after 1979, after construction of Oroville and New Melones dams. A review of the maximum daily inflow data for San Joaquin River shows similar results: three of the five largest single-day inflows have occurred since 1979, and seven of the 10 largest have occurred since 1979. The data in Table 2-4 also show no general trends in increasing or decreasing runoff to the Delta. Of the largest 25 inflows, 12 occurred during the most recent 25-year period, and 13 occurred during the first half of the 50-year period of record, thereby suggesting a somewhat stationary 50-year record. Smaller annual peak daily inflows would be expected after the addition of reservoirs in the watersheds if the reservoirs were reducing large flows, thereby suggesting that the additional dams may not significantly reduce total Delta inflows during major flood events. Also shown in Table 2-4 is the total volume of inflow that occurred during the peak inflow day and the four previous days. Although the total volume of available flood control storage in the watersheds during the flood events is not known, it is possible that runoff preceding the peak day filled whatever flood control storage was available and inflow into the reservoirs was not significantly greater than outflow on the peak day.

Another important factor to consider is the possibility that the flood control storage provided by a new reservoir only replaces a portion of the natural floodplain storage located downstream from the dam site. Under pre-dam conditions, large flood flows would overtop the channel banks and be temporarily stored on the floodplain, thereby attenuating peak inflows into the Delta. After construction of the dam, the flood flows would be temporarily stored in the reservoir, thereby attenuating the outflows and reducing or eliminating overtopping of the downstream channel banks and floodplain storage. Whether watershed storage is provided by reservoirs or the floodplain, inflows into the Delta are controlled, to some extent, by the capacity of the channels conveying runoff to the Delta.

Based on the foregoing, it does not appear that construction of reservoirs and other developments in the watersheds tributary to the Delta have a significant impact on annual peak daily Delta flood inflow characteristics during the period of record. Although it may be possible to adjust the inflow record to reflect all of the current reservoirs and watershed developments during the entire period of record, these adjustments would require significant effort and time not budgeted for these studies. Adjustment of the record would also require numerous assumptions regarding operations of the reservoirs during flood events and, most importantly, assumptions regarding levee failures and floodplain storage between the dams and Delta. These adjustments would probably incur more error than would result from using the inflow record without adjustment. For this reason and the previously discussed considerations, it is concluded that the entire 50-year period of inflow record would be used in the hydrologic risk analyses without adjustment. It is noted that this conclusion only applies to infrequent inflow events and not nonflood inflows.

Another consideration in the DRMS studies is the season of high inflows into the Delta. It is anticipated that repairing damages in the Delta, due to any cause, will be more difficult during the high-inflow season and the repairs will likely take longer. Additionally, the possible impacts on Delta exports caused by damages may be different depending upon the time of year that the damage occurs. Thus, hydrologic characteristics in the Delta during different inflow seasons were considered in the studies.

Figure 2-3 presents average daily Delta inflow versus time of the year for the period of record. As shown on Figure 2-3, high inflows begin near the end of December and last to about the middle of April. Between April 15 and December 15 maximum daily inflows are less than 200,000 cfs, and most of the time maximum daily inflows are less than 100,000 cfs, with the exception of one flood that occurred during October 14–17, 1962. Based on the above discussion the “high flow” season for purposes of the risk assessment was defined to run form December 15 to April 15 and the “low flow” season from April 15 to December 15.

3. Flow-Frequency Analyses

3.1 Flow Frequency

Flood frequency as used in this risk assessment has a slightly different definition than the definition typically used in flood studies. For purposes of the risk assessment, flood frequency in these studies provides a measure of the annual probability that the total inflow into the Delta will be equal or exceeded. The frequency associated with the total Delta inflow may not correspond to an equivalent frequency on any tributary or in the Delta. Many different inflow patterns into the Delta can produce any selected annual probability of occurrence, each of which could have its own set of water surface elevations in the Delta. For example, four storm events in the period of record have peak total daily inflows to the Delta that exceeded the 10-year event. For the largest storm of record, February 1986, San Joaquin River was not a significant contributor to the storm event, and Cosumnes and Calaveras rivers were. For the second-largest storm, January 1997, both Cosumnes and San Joaquin rivers experienced extreme events, and Calaveras

River did not. The third-largest storm occurred only on Sacramento River. Finally, for the fourth-largest storm, March 1983, an extreme event occurred only on San Joaquin River. The risk assessment needs to be able to account for all of these possible inflow patterns.

The magnitude of total Delta inflow for a hydrologic event of a given probability can be estimated from a frequency analysis of the measured annual peak inflow events. Table 3-1 summarizes the annual peak total Delta inflows for each of the 50 WYs of record, the 50 high-inflow seasons in the period of record, and the 49 low-inflow seasons in the period of record.

A commonly accepted frequency distribution of hydrologic events is the Log Pearson Type III (LPIII) distribution. This frequency distribution is recommended by the Hydrology Subcommittee of the Interagency Advisory Committee on Water Data published by the U.S. Geological Survey (USGS; USGS 1982). LPIII uses three distribution parameters: mean, standard deviation, and skew. Annual probabilities were calculated by using the data in Table 3-1 to estimate the distribution parameters.

Results of the LPIII analyses are presented in Table 3-2 and Figures 3-1, 3-2, and 3-3 for all water years analyzed (all seasons), high-inflow season, and low-inflow season, respectively. The distributions of seasonal peak daily inflows into the Delta are compared to the all-seasons distribution in Figure 3-4. Table 3-3 presents the estimated parameters for each distribution.

3.2 Probable Maximum Flood (PMF) Estimates

Figures 3-1, 3-2, and 3-3 and Table 3-2 present estimated flow frequencies for various confidence limits that were calculated for these studies. As shown by these figures and table, estimated total Delta inflows continue to increase as the probability of exceedance decreases (i.e., the LPIII methodology does not recognize a physical limit on the magnitude of total inflow).

For these studies, an approximation of the Delta PMF inflow was used as the physical upper limit of inflow magnitude. A statistical analysis of the PMF data presented in Table 2-1 was made and is presented on Figure 3-5. As shown by Figure 3-5, the relationship between PMF magnitude and drainage area can be approximated by the following equation.

$$Q = 15{,}223(A)^{-0.4650702} \qquad (3\text{-}1)$$

Where:

Q = PMF flow in cfs/square mile

A = Drainage area in square miles

According to the *California Water Plan Update 2005* (DWR 2005), the total area tributary to the Delta, including the Delta, is about 42,460 square miles. Based on the data presented on Figure 3-5, estimated PMF inflows into the Delta for various confidence limits were calculated and are presented in Table 3-4. The estimated PMF inflows presented in Table 3-4 represent the approximate upper limit of Delta inflows that were used for these studies. The best estimate (50 percent confidence) is approximately 4,500,000 cfs.

The information presented in Tables 3-3 and 3-4 was combined to develop Figures 3-6 and 3-7. These figures provide estimates of Delta inflow for various confidence limits for all water years analyzed (all seasons) and the high-inflow season, respectively, that consider both measured inflows and the physical upper limit of inflows that could be expected.

To combine the PMF estimates with the statistical analysis of measured inflows it was necessary to extrapolate the PMF data presented in Table 2-1 and Figure 3-5 and to assign a return frequency to the PMF flows. Neither schedule nor budget allowed for a site-specific PMF analysis of the Delta. It is recognized that extrapolation of the PMF data to include a drainage area as large as the Delta may result in an over-estimation of the Delta PMF. However, Delta inflows of interest in the risk analyses are significantly less that the PMF and, therefore, the probabilistic estimates of inflow are not sensitive to the PMF estimate. Additionally, it is recognized that a PMF is the physical upper limit of inflow that can occur based on meteorological constraints and, therefore, has no statistical probability of occurrence. For purposes of these analyses, the return frequency of a PMF was assumed to be about 1,000,000 years (probability of 0.000001). The relationships shown on Figures 3-6 and 3-7 between probabilities of 0.0001 and 0.000001 were visually interpolated. As shown by the plots, estimated Delta inflow is not highly sensitive to the assumed return frequency of the PMF.

3.3 Uncertainty

For the DRMS studies the epistemic uncertainty of the estimated inflow frequencies needed to be quantified. This quantification was performed by dividing the entire range of Delta inflows into smaller ranges (bins) and estimating the annual probability of occurrence of an annual inflow being in each of the bins.

The range of Delta inflows was divided into 17 bins where the difference in the natural logarithms of the upper and lower values of a bin is one-seventeenth of the difference in the natural logarithms of the upper and lower values of the total inflow range. The inflow limits for each of the 17 bins are given in Table 3-5. It was assumed that the representative inflow associated with each bin is the average of the upper and lower inflow values of the bin. The representative inflow for each bin is also presented in Table 3-5.

The difference in the annual probability of exceedance of the upper and lower value of a range of discharge, such as the discharge range of an inflow bin, is the probability of a discharge within the inflow range (bin) occurring during any given year. These probabilities of occurrence were estimated for the 5-, 20-, 50-, 80-, and 95-percent confidence limits and are summarized in Table 3-5.

The data presented in Table 3-5 can be used to estimate the annual return frequency of a discharge for a range of confidence limits. The confidence limits represent the epistemic uncertainty of the estimate, including the uncertainty in the LPIII skew coefficient.

3.4 Results

The frequency analyses of Delta inflows described above resulted in 17 ranges of total Delta inflow and the probability that the annual peak daily inflow will be within a particular range. Estimates are provided for 5 different confidence limits ranging from 5 percent confidence that the inflow will not be exceeded to 95 percent confidence that the inflow will not be exceeded. The estimated probability of an inflow being in each of the 17 ranges are given in Table 3-5 for each of the 5 confidence limits. Note that the inflow probabilities in Table 3-5 represent a range of inflows equal to the referenced inflow plus and minus 1/34th of the difference in the natural logarithms of the total range of inflows considered in the studies.

The 17 bins resulting from the above analysis represents the range of inflows that are likely to occur in the Delta (i.e., from 0 to 3,000,000 cfs). The Risk Analysis will use the flow from each bin in the risk analysis to cover the range of possible inflows. For each flow is associated an annual probability that that flow will occur (the probabilities are included in Table 3-5). Because there is uncertainty in the estimate of the annual probability that a given flow will occur, the risk analysis will also associate a confidence bound with each annual probability. This results in five estimates of the probability of occurrence for each inflow.

4. Delta Inflow Patterns

4.1 Introduction

Inflow to the Delta is from several sources including the Yolo Bypass (Yolo), Sacramento River (Sac), Cosumnes River (CSMR), Mokelumne River (Moke), San Joaquin River (SJR), and miscellaneous streams (misc). Miscellaneous streams consist primarily of the Calaveras River. The locations of these flow stations are shown on Figure 2-1. The sum of these sources of inflow is defined as the Total Delta Inflow (TDI). Given the variability of flows in the streams making up TDI, there are many possible combinations of flows that could account for any TDI observed. This section describes a method for defining different Delta inflow patterns that could account for any selected TDI.

Flow data used in the flow pattern analyses are the same as described in Section 2. This dataset consists of 50 years of daily average inflow values from October 1, 1955, through September 30, 2005. However, most of these data represent flows during summer or non-storm winter conditions. Flow patterns that occur during these conditions are controlled to some extent by reservoir releases, are likely different than those during storm events, and are not relevant to the study of the risk of levee failure during a major hydrologic event. A somewhat arbitrary cutoff value of 200,000 cfs was selected to eliminate non-flood inflow patterns, even though flood inflows less than 200,000 cfs are considered in the probability analyses, i.e., we did not want to bias the probabilistic inflow patterns by including small inflows that may be dominated or strongly influenced by reservoir releases. A total Delta inflow of 200,000 cfs corresponds to a 50 percent confidence peak annual return period flow of about 3 years.

Table 4-1 summarizes flow data used in the analyses of inflow patterns. The majority of inflow into the Delta, approximately 85 percent on average, is from Sacramento River and Yolo Bypass. The statistics provided in Table 4-1 show that flows in Sacramento River are not highly variable (the coefficient of variation is only 0.084) and that most of the variability is due to flows in Yolo Bypass. Flows in these two channels are not independent because the flows originate from the same watershed. Upstream of the City of Sacramento, when the stage in Sacramento River reaches the crest of Fremont Weir, flow in Sacramento River spills into Yolo Bypass. This spill condition occurs at a flow of about 55,000 cfs in Sacramento River, as measured below the weir. Most of the increase in flow above 55,000 cfs goes over the weir into Yolo Bypass. The Yolo Bypass Working Group et al. (2001) developed a relationship between flows in the Sacramento River below Fremont Weir and spills over the weir. The relationship indicates that it is only necessary to be able to predict one of the stream flows (Sacramento River or Yolo Bypass), and the other stream flow can be estimated. For this reason, the method presented below is used to predict the sum of flow in Sacramento River and Yolo Bypass.

4.2 Method

The method for estimating flow in any of the contributing tributaries to the Delta given a specified TDI is to use regression relationships for each contributing inflow. A constraint on the choice of the relationship is that for any TDI (even TDIs beyond what have been observed) the sum of the flows developed from the relationships must add up to the TDI. Therefore, the relationships cannot be independent of each other. The dependence between relationships was maintained by only applying the relationship to that portion of the flow not yet explained by any previously used relationship. The general form of the relationships listed below shows this dependence (five inflows occur if the sum of the Sacramento River plus Yolo Bypass is considered as one inflow).

Q(inflow1) = function (TDI) (4-1a)

Q(inflow2) = function (TDI–inflow1) (4-1b)

Q(inflow3) = function (TDI-inflow1-inflow2) (4-1c)

Q(inflow4) = function(TDI-inflow1-inflow2-inflow3) (4-1d)

Q(inflow5) = TDI-inflow1-inflow2-inflow3-inflow4 (4-1e)

Use of the above relationships will assure that the contributions from each of the tributaries will add up to the TDI only if Q(inflow5) is unconstrained (i.e., can take on any value including negative values). To constrain Q(inflow5) to only positive values and to values that are representative of the actual observed values, the regression function needs to be chosen such that:

$$Q_i \leq RI_i \quad (4\text{-}2)$$

Where:

$$RI : R_i = TDI - \sum_{j=1}^{i-1} Q_j$$

$Q_i > 0$ and $Q_0 = 0$

That is, flow in any river [Q(inflow)] has to be less than the remaining inflow (RI).

Using a linear relationship between the logit function and the available inflow as the function in Equations 4-1a through 4-1d guarantees that Equation 4-2 will be satisfied for any value of TDI. This is commonly referred to as logistic regression (Neter and Wasserman, 1974). The logit function is defined as:

$$\text{logit}(p) = \ln\left(\frac{p}{1-p}\right) \qquad (4\text{-}3)$$

Where p = the fraction of available flow. Using the terms from Equation 4-2,

$$p = (Q_i)/(RI_i) \qquad (4\text{-}4)$$

and p will always be between 0 and 1. Equation 4-4 could also be written as

$$p = Q\,(\text{river})/RI.$$

Equation 4-5 gives the general form of the logistic regression.

$$Y' = a*\text{Ln}(RI) + b \qquad (4\text{-}5)$$

Where Y' = logit(p), is given by Equation 4-3, and "a" and "b" = constants determined from the regression of Equation 4-5 applied to the 50 years of data.

Once constants "a" and "b" are known, flow in any river can be calculated from a selected value of TDI using Equations 4-3, 4-4, and 4-5:

$$Q(river) = \frac{RI * \exp(a * \ln(RI) + b)}{1 + \exp(a * \ln(RI) + b)} \qquad (4\text{-}6)$$

Where:

RI is calculated from Equation 4-2.

The order in which the regressions are applied can affect the values of the constants "a" and "b". The best results are obtained when the regressions are applied in order starting from highest inflow (Sacramento River + Yolo Bypass) to the lowest inflow (Mokelumne River). The order of calculating the regressions was: Sacramento + Yolo, followed by the San Joaquin River, miscellaneous flows, the Cosumnes River then the Mokelumne River. The analysis was tried with the above order and with the Cosumnes River and miscellaneous flows reversed. With the Cosumnes and Miscellaneous flows reversed the regression was biased to underestimating the flow rate.

4.3 Results

Table 4-2 lists the results of the logistic regression. The r^2 values for the fit of the logistic regression are near zero except for the Cosumnes River. The low r^2 values result from the large variability in the data. However, even with these small correlations, the equations reproduce the mean values for the flow distributions, as described in Section 4.4.

Figure 4-1 compares the predicted to the measured flows in the Sacramento River plus Yolo Bypass. The correlation coefficient for the fit is 0.94.

In addition to the above results, a relationship between the flow in Sacramento River and Yolo Bypass is needed to separate these two flows from the total. Figure 4-2 shows the relationship.

Figure 4-3 compares the predicted and measured flows for San Joaquin River. The correlation coefficient for the fit is 0.65. The regression equation provides a reasonable fit, though it underpredicts slightly the main body of the data due to the small number of cases where the remaining flow is large and the fraction of flow in San Joaquin River is small (~10 percent of values). These events represent cases where a storm occurred on the Cosumnes River but not on the San Joaquin River. Since the method used to generate the flow distributions assumes that the magnitude of the flows can be ranked in a consistent order (i.e., $Q_{sact+yolo} > Q_{sjr} > Q_{misc} > Q_c > Q_{mok}$) those storms that do not follow this pattern will not be captured in the regression. The variability will be captured as described in Section 4.4. The regression over-predicts the peak annual flows.

Figure 4-4 presents the results for the miscellaneous inflows. The correlation coefficient for the fit is 0.94.

Figure 4-5 shows the results for the Cosumnes River. The correlation coefficient for the fit is 0.96, though it underestimates the peak annual flows.

4.4 Validation of Method

For the above methodology to be valid, it should be able to reproduce the statistics of the data used in its development, both in data mean and variability. Table 4-3 compares the statistics of the observed flows and predicted flows.

The regression relationships reproduce the mean and median of the data well except for the median of Cosumnes River inflows. For most of the rivers, the mean flow is centered within the bulk of the observed flows (e.g., halfway between the 25th and 75th percentiles), whereas for Cosumnes River the mean is almost at the 75th percentile. This implies that the distribution of inflows from Cosumnes River is more skewed than the inflows from other rivers and, therefore, the regression will not reproduce the median values as well.

Figures 4-6 through 4-9 compare measured to predicted flow for the Sacramento River plus Yolo Bypass, San Joaquin River, miscellaneous inflows, and Cosumnes River, respectively. All of the figures show a very good fit between the measured and predicted flows except for the San Joaquin River cases in which the flows in other streams exceeded the flow in San Joaquin River. These values do not fit the relationship and need to be captured as part of the uncertainty analysis.

The regression equations do not predict the variability in the inflows since regression equations can only provide a prediction of the mean value. To predict the variability, the standard error of the regression was used to estimate variability around the mean. For any estimate, the Equation 4-7 gives the variability around the mean value:

$$Y_\alpha = Y' \pm k_\alpha \sigma \qquad (4\text{-}7)$$

Where:

Y_α = Flow parameter with confidence α

Y' = mean estimate of the flow parameter from Equation 4-5

k_α = the confidence coefficient

σ = standard error or the regression

Equation 4-7 applies when the variability around the mean is normally distributed. This is true in logistic space where the regression coefficients were calculated using Equation 4-5. Equation 4-8 is used to transform the results to arithmetic space.

$$Q_\alpha = \frac{RI_\alpha * \exp(Y_\alpha)}{1 + \exp(Y_\alpha)} \tag{4-8}$$

5. Delta Water Surface Elevations

5.1 General

Estimates of water surface elevations throughout the Delta that are associated with various inflow magnitudes, inflow patterns, and downstream tide levels are needed to estimate risks of levee failure due to overtopping and/or high water. Water surface elevations in the Delta were estimated from data on historic water levels measured at selected Delta gauging stations. Water levels, or stages, at the selected gauging stations were then used to interpolate stages at intermediate locations in the Delta. This section discusses the methodology and results of flood stage estimates in the Delta.

5.2 Data Acquisition

5.2.1 Tide Data

Maximum daily tides measured at the San Francisco station (NAVD 88 datum) were compiled for the period January 1, 1956 through April 15, 2006, approximately the same 50-year record used in the Delta inflow frequency analyses. A plot of the maximum daily tides versus date was made and a linear regression analysis of the data indicated a steady increase in the maximum daily tide during the 50-year record. Consequently, the data were normalized to January 1, 2000 by subtracting the best estimate for each daily measurement and adding the residual to the best estimate for January 1, 2000, thereby providing a consistent record of maximum tide for current (year 2000) conditions. The tide data are available at the following website:

http://tidesandcurrents.noaa.gov/station_retrieve.shtml?type=Historic+Tide+Data

Tide measurements during the high Delta inflow season (December 16 through April 15) of each year were extracted from the normalized maximum daily tides at the San Francisco station and a frequency analysis made of the resulting data set. The range of maximum daily tide during the 50 years of normalized high-inflow season tides is 3.88 feet to 9.01 feet. The 6,080 normalized tide measurements were sorted into 22 tide ranges (bins), with each tide range being 0.25 feet. The probability of a maximum daily tide being in a given tide range was calculated. Results of these calculations are presented in Table 5-1 and Figure 5-1.

Table 5-1 presents the probabilities of a maximum tide on any given day. For purposes of the risk analyses, tides are assumed to be independent of inflow events. Although this assumption may not be true for all inflow events, extreme tides (which include storm surges) are generally concurrent with the storm events, whereas the Delta inflow event associated with the storm occurs considerably after the storm event.

5.2.2 Stage Data

The California Data Exchange Center (CDEC) provides information on an extensive hydrologic data collection network, including automatic river stage sensors in the Delta. River stage data are provided primarily from the stations maintained by the DWR and USGS. The stage data can be downloaded from the CDEC website (CDEC, no date; http://cdec.water.ca.gov/queryCSV.html).

Stage data are provided on an hourly basis since 1984. For some gauging stations, 15-minute stage levels have been recorded for some inflow events since 1995. Figure 5-2 shows the locations of the stage gauging stations selected for use in these studies and presents the period of record for hourly and event data for each station. Gauging stations were selected based on station location and length of available record.

5.3 Data Review and Adjustments

Stage records for the selected gauging stations contained some inconsistent data that are significant enough to have an impact on the results of the analyses. To assist in evaluation of the stage data, plots of daily stage versus time were created for each of the measuring stations. These plots provide a picture of the normal stage range and also show apparent inconsistencies in the data. The data records were evaluated and, when possible, adjusted to eliminate apparent invalid data. The data records were reviewed to adjust or eliminate the following inconsistent data:

- Changes in station datum
- Measured stages exceeding realistic stage elevations
- Missing and known invalid data
- Constant stage measurements
- Invalid recording intervals
- Incomplete daily records

5.3.1 Changes in Station Datum

At some stations, the local station datum was shifted 2 to 3 feet during the period of record. These shifts were not applied to the preceding data record and, in some cases, not mentioned in the metadata for the station. These changes in the station datum are generally obvious in the station record, as illustrated in Figures 5-3 and 5-4.

In discussing changes in station datum with DWR personnel it was agreed that, in general, these datum changes were made for one of two possible reasons:

- To change the station datum from National Geodetic Vertical Datum of 1929 (NGVD 29) to North American Vertical Datum of 1988 (NAVD 88), which shifts the data range by 2 to 3 feet. The magnitude of these shifts can be calculated using the station latitude and longitude as provided at the DWR website (http://cdec.water.ca.gov/staMeta.html). For these records, portions of the data record were adjusted to provide a common datum for the entire period of record.
- Datum changes were made at some of the older stations because the mechanical recording device used at the time had difficulty recording negative values. In these instances, the stage records were adjusted upward by 3 feet to avoid recording negative numbers. Again, the data in the early years were adjusted by 3 feet to provide a common datum for the entire period of record.

5.3.2 Measured Stages Exceeding Realistic Stage Elevations

Some of the records contained values of stage for greater than the normal flood stage for the station. These anomalous data are generally at the beginning of the record or during maintenance of the station and may have been recorded before the equipment was fully calibrated and a datum established. These apparent anomalies were assumed to be invalid and were removed from the dataset.

5.3.3 Missing and Known Invalid Data

Some of the available data were recorded as a large negative value such as -9999.99 or as an alpha value such as “m.” These data were either not recorded or known to be incorrect for some reason. These data were eliminated from the dataset.

5.3.4 Constant Stage Measurements

Some data records present constant values of stage for extended periods of time. Given that stages are measured to the hundredth of a foot and that stage is impacted by tides, it is expected that recorded stages will fluctuate. Occasionally there are stretches of data with the same elevation repeated for the entire day or multiple days. These data were assumed to be invalid and not used.

5.3.5 Invalid Recording Intervals

Some of the event (quarter-hour) data are recorded at time intervals not on the quarter hour or on a one minute or 5-minute interval. Any data not on the quarter hour or hour were discarded.

5.3.6 Incomplete Daily Records

Each day has 24 stage measurements for hourly data and 96 measurements for quarter-hour event data. Some of the days in the records did not have a complete set of measurements. These studies focused on determining the maximum stage in a given day.

To increase the probability that a measurement that is near the highest stage is included in the record, only days with at least 20 hourly measurements or 76 quarter-hour measurements were retained in the dataset.

5.4 Conversion of Data to a Known Common Datum

Review and adjustment of the data as discussed in Section 5.3 provides a record for each station that has a single datum for all of the data at each station. However, not all of the selected stations have the same datum, and in some instances it is not known if the datum is NGVD 29, NAVD 88, or some local datum. To compare stations it was necessary to convert all of the station records to the NAVD 88 datum.

The average stage for complete tide cycles (28-day cycle) during August of several water years was calculated for each of the Delta stations. August was selected for these calculations because it is consistently one of the low Delta inflow months. During low inflows, the stages at most stations are primarily a function of tide and not flow, particularly in the central and western part of the Delta.

The average stage at each of the Delta stations were compared to the average stage for the same period at the Golden Gate tide station, which has a known mean sea level (MSL) of 3.39 feet NAVD 88. If the August inflows into the Delta were essentially zero, then the difference between the low flow (August) station average stage and the average August tide elevation at Golden Gate could be used to adjust the datum at each of the Delta stations. However, the August inflows are not zero, and therefore the inflows have some effect on the average measured stage at each station, resulting in a measured stage slightly higher than the August MSL at Golden Gate.

To account for the slightly higher Delta stage levels due to the low August inflows, approximations of the stage increases caused by the inflows were made using data from the more reliable gauging stations in the Delta. Delta stations used to develop the approximate datum adjustments for inflow are summarized in Table 5-2. All of the stations listed in Table 5-2 have reliable records with a known datum that can be directly converted to NAVD 88. For these stations, the stage increase due to the low inflows can be directly calculated as the difference between the Golden Gate station August MSL and the average NAVD 88 August stages. These differences were then used to further refine the estimates of NAVD 88 mean sea level at the Delta stations. Calculation of stage increases due to the low August inflows are summarized in Table 5-2.

The Mallard Island gauging station is located just west of Pittsburg and east of Suisun Bay. It was used to represent the bottom or exit point from the Delta. The elevation differences shown on Table 5-2 represent a very mild hydraulic gradient between the station location and the Mallard Island station (less than approximately 1×10^{-5} feet per foot gradient). For example, the distance from the Freeport station to the Mallard Island station is approximately 40 miles and the difference in stage between these stations is 2.93 which results in a hydraulic gradient of 0.00001. Gradients for other stations are also shown in Table 5-2.

Table 5-3 summarizes the adjustments made at all of the selected gauging stations in the Delta to convert the data to NAVD 88. Adjustments for August inflows were calculated for those stations listed in Table 5-2. In most cases no adjustment was required. For stations in Table 5-3, where August inflow adjustments were calculated, adjustments were estimated based on the known artificial adjustment of the recording device as described in Section 5.3.1 or on the conversion factor from NGVD 29 to NAVD 88 calculated from each station's latitude and longitude.

5.5 Regression Analyses of Water Surface Elevations

5.5.1 Matching Station Elevation to Tide and Flow

Once maximum daily stage data were reviewed, invalid records removed, and conversion to NAVD 88 datum estimated for each station, the daily stage data were compiled with the corresponding maximum daily tide data and the mean daily inflow data for each tributary stream. The resulting data set is a daily record of maximum daily stage (NAVD 88 datum), maximum daily tide, and mean daily inflow from each of the six tributary inflows into the Delta.

This study focuses on the threat from high stages that occur during flood events. Most of the inflow data in the data sets represent low-inflow non-flood events. To minimize bias in the statistical analyses of water surface elevations, the inflow data sets were reduced to only include high inflow events. Based on review of the data it was judged that only TDI magnitudes greater than 57,000 cfs should be included in the regression analyses.

5.5.2 Regression Analyses of Water Surface Elevations

Using the data on maximum daily tide, mean daily inflow, and measured adjusted stages at the gauging stations, multiple regression analyses were made for each of the stage measuring stations. The regression analyses were made to determine best fit coefficients for Equations 5-1 and 5-2. Either Equation 5-1 or 5-2 was used in the regression analyses, depending upon the stage measuring station being analyzed. Equation 5-1 was used to estimate stages at the Freeport (FTP) and Lisbon (LIS) stations because stages at these stations depend upon flow in Sacramento River and Yolo Bypass respectively, and not the combined flows in Sacramento River and Yolo Bypass. Equation 5-2 was used for the other stage measuring stations because the measured stage better correlates with the combined Sacramento River and Yolo Bypass flows.

$$WSE_i = aT + b(Q_{Sac})^{b'} + c(Q_{Yolo})^{c'} + d(Q_{SJ})^{d'} + e(Q_{Cos})^{e'} + f(Q_{Mok})^{f'} + g(Q_{misc})^{g'} \qquad (5\text{-}1)$$

$$WSE_i = aT + b(QSac+QYolo)^{b'} + d(QSJ)^{d'} + e(QCos)^{e'} + f(QMok)^{f'} + g(Qmisc)^{g'} \qquad (5\text{-}2)$$

Where:

WSE_i = water surface elevation at station "i"

T = Golden Gate maximum daily tide elevation

Q_{Sac} = Sacramento River inflow

Q_{Yolo} = Yolo Bypass inflow

Q_{SJ} = San Joaquin River inflow

Q_{Cos} = Cosumnes River inflow

Q_{Mok} = Mokelumne River inflow

Q_{misc} = miscellaneous inflow

The theoretically derived weir equation and Manning's Equation for a simple river (e.g., cross-sectional area equal width times depth) indicate that discharge per unit width of flow (q) is proportional to the hydraulic head to the 1.5 power, or, conversely, the hydraulic head is proportional to discharge to the 0.67 power (Streeter and Wylie (1979). Thus, the exponents b' through g' in Equation 5-1 and 5-2 were set equal to 0.67. A similar argument can be made for orifice flow under a sluice gate. Coefficients "a" through "g" are determined from the regression analyses.

Each component of Equation 5-1 and 5-2 represents the contribution to the expected stage of tide and flow from each inflow source.

In the regression analyses, a condition was imposed on the "a" through "g" coefficients to restrict these coefficients to positive values. Negative values of these coefficients would indicate a decrease in stage for an increase in flow, which is not realistic.

Regression analyses were performed for the 15 stage measuring stations listed in Table 5-3. The multiple linear regression analyses were solved in two steps. In the first regression, the average absolute error was minimized. In the second regression, the average error was minimized. The absolute average error ranged from 0.17 feet to 0.92 feet.

The coefficients "a" through "g" derived from the regression analyses are presented in Table 5-4. The resulting average absolute error and maximum error were determined and are also presented in Table 5-4.

5.6 Evaluation of Flood Stage Equations

At each station the measured water surface elevation was compared to the calculated water surface elevation using the coefficients listed in Table 5-4. Figure 5-5 compares the calculated stage with the measured stage at Venice Island. Similar comparisons for the stations listed in Tables 5-2, 5-3, and 5-4 are provided in Appendix A. In addition, the observed annual peak at each station is compared to the predicted annual peak for stations with four or more years of data. For most stations, the root mean square error is equal to 0.34 feet or less. Only two stations, Benson's Ferry and Liberty Island, have root mean square errors that are greater than 1 foot.

5.7 Interpolation of Stages at Intermediate Locations

Given the coefficients "a" through "g", a stage elevation can be predicted at each of the selected stage measuring stations (primary stations) for any inflow pattern and tide condition. Stage estimates are also needed at locations where measured data are not available. Critical locations were selected, such as stream junctions and the stage at these locations (secondary stations) was estimated by linear interpolation of the distances along the primary Delta channel flow path between primary locations that passed through the secondary station. The locations of the interpolated secondary stations are shown on Figure 5-2.

5.8 Assumptions and Limitations

These analyses assume a channel system within the Delta that is regular and that behaves consistently over the period since 1984 when stage data first became available. At least two artificial (human-made) conditions exist in the Delta waterways that may account for some of the error found in the equations.

The weir near the Lisbon station can be operated to release flows at different stage elevations on Sacramento River. The relatively high error for this station may partly result from water releases made at different stage elevations over the past 22 years. For example, operators may choose to begin to release water at a lower than usual stage elevation to minimize the danger to urban areas from higher flows expected in the near future. These operational issues have not been explored in these analyses.

The Delta Cross Channel near Walnut Grove may also be operated in a manner that could impact the accuracy and consistency of the equations developed in this memorandum, though the gates at this facility are generally closed during the high inflow season. For the purposes of these analyses, the impacts of operations at these two structures do not change significantly the results of these studies.

Finally, these analyses assume that failures in the levee system for any given inflow condition will not significantly reduce the downstream stage along the channels. This may or may not be the case depending upon the magnitude of the flood inflow, when the breach occurs, and the volume of the breached island. For those cases were a levee breach occurs before and during the peak water surface elevation and the flood inflow volume is relatively small, then this assumption will over predict downstream water surface elevations.

It should be noted that the equations for predicting stage were derived from actual measurements of inflows, tide, and stage. When the equations are used to predict stages during hydrologic events that are more severe than those included in the data set, they may, in many cases, predict stages that are higher than the levee crests. To the extent that levee overtopping (and possible levee failure) will convert the flooded island(s) into an effective conveyance channel through the Delta then the predictor equations would over estimate stages. The equations are only intended to predict how high the flood flows are on the levee banks and if the levees are overtopped. They are not intended to predict stages in excess of the levee crests.

6. Future Hydraulic Risks

6.1 Data

Two different climate models and two different climate change scenarios were used to estimate daily flows in 23 watershed streams, which provided four different 150-year records of daily flows. The climate models and climate change scenarios are described in *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1, Topical Area – Climate Change* (DWR 2007) and the *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1, Topical Area – Water Analysis Module (WAM),*

Appendix F. The results are provided as Special Report on Emissions Scenarios (SRES). The four different scenarios characteristics are listed below:

Scenario Name	CO_2 increase	Global Climate Model (GCM) used
SRESa2 – gfdl	CO_2 emissions continue to accelerate	National Oceanic and Atmospheric Administration (NOAA) Geophysical Fluid Dynamics Laboratory (gfdl)
SRESb1 - gfdl	rate of emissions growth moderates and the emission rates themselves eventually decrease	National Oceanic and Atmospheric Administration (NOAA) Geophysical Fluid Dynamics Laboratory (gfdl)
SRESa2 - ncar	CO_2 emissions continue to accelerate	Parallel Climate Model (pcm), by the National Center for Atmospheric Research (ncar)
SRESb1 - ncar	rate of emissions growth moderates and the emission rates themselves eventually decrease	Parallel Climate Model (pcm), by the National Center for Atmospheric Research (ncar)

The DRMS climate change task group developed synthetic estimates of runoff in 23 major streams tributary to the Delta. These estimates provided daily mean runoff rates, in cfs, for the 150-year period from 1951 through 2100. The runoff estimates generally apply to locations upstream from reservoirs in the watersheds tributary to the Delta. These data were used to develop estimates of Delta inflow probabilities in future years.

A key assumption in using the synthetic runoff records to estimate probabilities of future inflows is:

> *The future change in frequency of a watershed event with a given current return frequency will produce the same future change in frequency for the Delta inflow of the same current return frequency*.

In other words the shift in the frequency curve for Delta inflow will be the same as the shift in the frequency curves for watershed runoff. For example, if the current 100-year watershed runoff event has a 50-year return frequency in year 2100, then the current 100-year Delta inflow event will have a 50-year return frequency in year 2100. This assumption may not be accurate if daily runoff values are used because estimated inflows into the Delta in some streams during some storm events may be significantly attenuated by reservoirs located between the runoff locations and the Delta. This potential inaccuracy can be reduced by defining the watershed event as the average runoff in the streams that occurs over a period of several days, thereby attenuating and smoothing the flows in a manner similar to that of a reservoir.

For purposes of estimating future probabilities of Delta inflows, the annual watershed runoff event was defined as the largest annual value of the 7-day sum of total daily runoff amounts in the 23 streams. In other words, the estimated daily runoff volumes in each of the 23 streams were added together to give 150 years of daily sums. A 7-day running total was calculated for record, and the largest value in each year was selected as the annual event.

Annual watershed runoff events, calculated as described in the preceding paragraph, were determined for each of the four climate change scenarios and evaluated to identify future changes in hydrologic events and select periods of the records to be used in estimating Delta inflow events. Figure 6-1 presents the cumulative sum of annual peak runoff events in the watershed for each of the four climate change scenarios. As shown in Figure 6-1, the trend in cumulative peak runoff with time is linear and essentially the same for the four scenarios for the period 1950 to about 2010. After approximately year 2010, cumulative peak runoffs for the four scenarios begin to deviate from the earlier linear relationship. This means there are no noticeable climate change impacts prior to year 2010, and the 1951 to 2000 period of record can be used to represent current hydrologic conditions. Therefore, the period 2026 to 2075 is used to estimate hydrologic conditions in the year 2050, and the period 2051 to 2100 is used to estimate hydrologic conditions in the year 2075.

6.2 Frequency Analyses

Having defined and estimated watershed runoff events as described in Section 6.1, the following steps were used to estimate Delta inflow under future climatic conditions in years 2050 and 2100.

6.2.1 Step 1: Determine Data Skew for Frequency Analyses

Frequency distributions for each of the four synthetic records were analyzed in 50-year segments. Fifty data points of annual peak runoff were not sufficient to define the data skew coefficient, resulting in varying skew coefficients for each 50-year segment of record and large variations in the analyses results. Thus, it was decided to use the skew coefficient associated with the 150-year record. In the LPIII distribution, the skew used is that of the natural logarithm of the annual peaks. These skew coefficients were calculated for each of the four future climate scenarios as:

Scenarios (as described in DWR 2007)	150-Year Skew of Natural Logarithm of Annual Peak
Sresa2-gfdl	-0.263432
Sresa2-ncar	-0.108138
Sresb1-gfdl	-0.140541
Sresb1-ncar	-0.246774

6.2.2 Step 2: Calculated Log Pearson Type III Frequency Distributions

For each of the future climate scenarios and their associated skew coefficients, LPIII frequency distributions were fit to the data for the periods 1951 to 2000, 2001 to 2050, 2026 to 2075, and 2051 to 2100 in each 150-year record. The period 1951 to 2000 was used to represent current hydrologic conditions. The period 2001 to 2050 was used to represent hydrologic conditions in 2025, the period 2026 to 2075 to represent hydrologic conditions in 2050, and the period 2051 to 2100 to represent hydrologic conditions in 2075. For each probability distribution analysis, 5 percent, 20 percent, 50 percent, 80 percent, and 95 percent confidence limits were calculated. Figure 6-2 illustrates the results of the analysis of the 50 percent confidence limit calculation using future climate scenario Sresa2-gfdl.

6.2.3 Step 3: Estimate the Probability of Year 2000 Runoff Values Occurring in Future Years

Probabilities of exceedance for selected peak annual watershed runoff amounts were estimated for present and future climate conditions using the curves developed in Step 2. Table 6-1 illustrates estimated probabilities for climate scenario Sresa2-gfdl with a 50 percent confidence limit, as derived from the plots in Figure 6-2. The scales presented in Figure 6-2 had to be greatly expanded to estimate the probabilities presented in Table 6-1. The estimated probabilities of exceedance for years 2000, 2025, 2050, and 2075 were extrapolated to produce estimates of the probabilities of exceedance of the selected runoff magnitudes in year 2100. These estimates are also presented in Table 6-1. Note that the discharges presented in Table 6-1 represent annual peaks of the 7-day total runoff in the 23 watershed streams.

6.2.4 Step 4: Convert Watershed Runoff Events to Delta Inflow Events

As previously discussed, it is assumed that shift in the frequency distribution that occurs in the watershed under future conditions will produce the same shift in the frequency distribution of Delta inflows. This adjustment results in the Delta inflow magnitudes and probabilities of exceedance for years 2000, 2050, and 2100 that are shown in Table 6-2 for the Sresa2-gfdl climate change scenario. The estimates presented in Table 6-2 were also developed for the other three climate change scenarios.

6.2.5 Step 5: Select Ranges of Delta Inflows (Bins) for Analyses

Examination of the data in Table 6-2 and similar data for the other three climate change scenarios indicates that the infrequent annual peak Delta inflows in the future will be larger than during current climate conditions. To include all potential inflow events that could significantly contribute to Delta risks, the range of inflows selected for analysis of future conditions was from a low of 200,000 cfs to a high of 5,000,000 cfs. As shown by the data in Table 6-2, this range includes year 2100 inflows from approximately a 450-year event at the 95 percent confidence limit to approximately a 5-year event at the 5 percent confidence limit.

The total range of inflows (200,000 to 5,000,000 cfs) was divided into 15 bins. As with the analyses of current conditions discussed in Section 3, the difference in the natural logarithm of the upper and lower discharge limits of each bin is equal to one-fifteenth of the difference in the upper and lower limits of the total range. The range of inflows associated with each bin and the designated bin discharge are presented in Table 6-3. The designated bin value is the mean of the upper and lower inflow for each bin.

6.2.6 Step 6: Estimate Probabilities of Inflows Being in a Designated Range (Bin)

As with the probability estimates of current Delta inflows discussed in Section 3, a limit was set on the maximum possible inflow under future conditions. For the analyses of current conditions, the maximum was set at a value comparable to the PMF. It was assumed that the current condition maximums presented in Section 3 would increase by 10 percent for year 2050 conditions and increase by 20 percent for year 2100 conditions. As discussed in Section 3, the sensitivity of the study results to the assumed increases in PMF is small.

The data provided in Table 6-2 and similar data for the other three climate scenarios were combined with the bin data in Table 6-3, and the increased upper limits of Delta inflow was used to prepare plots of inflow versus probability of exceedance. An example of the plots is presented in Figure 6-3 for year 2100 conditions and climate scenario Sresa2-gfdl.

Using the plots similar to Figure 6-3, probabilities of exceedance were determined for the upper and lower discharge limits of each of the 15 bins for each of the study years (2000, 2050, and 2100) and each of the four climate change scenarios. Results of these estimates are illustrated in Table 6-4 for climate change scenario Sresa2-gfdl.

The difference in the probabilities of exceedance of the upper and lower inflow values of each bin is the probability that the inflow will be in the inflow range of the bin. The probabilities of inflows being in a designated bin range were calculated for each of the 15 bins for each of the study years (2000, 2050, and 2100) and each of the four climate change scenarios. Results of these estimates are illustrated in Table 6-5 for climate change scenario Sresa2-gfdl.

The data presented in Table 6-5 and similar data for the other three climate scenarios were smoothed by plotting the data and calculating equations that best fit the data. Figure 6-4 illustrates the relationships between mean bin inflow and the annual probability of a hydrologic event being in bin inflow range for year 2100 and climate change scenario Sresa2-gfdl.

6.3 Results of Frequency Analyses for Future Climate Conditions

Mean inflow values and the range of inflows for each bin used in the analyses of future climate conditions are summarized in Table 6-3. Equations giving the probabilities of a future hydrologic event being in a particular bin range are summarized in Table 6-6 for years 2050 and 2100 and confidence limits of 95, 80, 50, 20, and 5 percent.

6.4 Future Delta Inflow Patterns

Analyses of the synthetic runoff data for climate change scenario Sresa2-gfdl were made to determine if the inflow patterns discussed in Section 4 would be different in future years. For each of the 23 streams included in the record, the 7-day runoff amounts that contribute to the 43 largest annual watershed runoff events were extracted from the data set. The 43 largest annual runoff events consist of 16 events during the period 1951 through 2000, 13 events during the period 2001 through 2050, and 14 events during the period 2051 through 2100. For each of the 50-year periods, the average percent contributions to the runoff events were calculated for each of the 23 streams. Results of these calculations are presented in Table 6-7.

Examination of the data in Table 6-7 shows no significant time-dependent trends, either on an individual stream basis or on a regional basis. Based on these analyses, it was decided that the same Delta inflow patterns would be used for years 2050 and 2100 as were developed in Section 4 for current conditions.

6.5 Future Delta Water Surface Elevations

Water surface elevations in the Delta will change in the future due to rising sea levels. The increases in sea level cannot simply be added to the water surface elevations estimated as described in Section 5; the sea level rise will change the hydraulic characteristics of flows through the Delta and its impact should decrease the farther inland a location is and the larger the storm event is. A simple method to approximate changes in water surface elevations in the Delta due to sea level rise was developed and is described in the following paragraphs.

A rise in sea level increases the tailwater that inflows must overcome to pass through the Delta and enter San Francisco Bay. For any given inflow magnitude and pattern flow, depths in the Delta channels will be larger, thereby reducing flow velocities and hydraulic head losses. The reduction in hydraulic head loss must be accounted for in estimating water surface elevations under future increased sea level conditions. The following assumptions were made in analyzing sea level rise in the Delta:

1. Manning's Equation can be used to describe the flow in the Delta channels during storm events.
2. The channels are much wider than they are deep; therefore, the hydraulic radius can be approximated as the channel depth.
3. The slope of the channel can be approximated as the water surface slope between the station of interest and the next downstream station.
4. The water surface elevation at any station can be approximated using the relationships developed in Section 5.

Using the above assumptions, the sea level rise at any location in the Delta can be estimated using Equation 6-1.

$$\left(\frac{h_B}{h_B + d_B}\right)^{5/3} = 1 + \frac{d_B - d_A}{f_B(Q_i) - f_A(Q_i)} \qquad (6\text{-}1)$$

Where:

h_B = water depth at location of interest

d_B = sea level rise at point of interest

d_A = known sea level rise at downstream point

$f_B(Q_i)$ = water surface elevation at point of interest calculated from relationships in Section 5

$f_A(Q_i)$ = water surface elevation at point downstream calculated from relationships in Section 5

Equation 6-1 is applied starting from the farthest downstream point (e.g., the Mallard Island station) moving upstream.

7. Summary

The purpose of the Flood Hazard analysis presented in this technical memorandum is to develop inputs needed for the Risk Analysis Report. These inputs include inflow magnitudes and patterns, water surface elevations, and the probabilities and uncertainties of occurrence of these inputs. Since the Risk Analysis Report simulates a large number of scenarios, the methods used to generate the hydrologic inputs to the Risk Analysis need to be simple and robust.

Daily total Delta inflow, which is referred to as TDI throughout this TM, measured in cfs was chosen as the parameter to define a hydrologic event in the Delta. Average daily inflows into the Delta available from the California Department of Water Resources (DWR) website for the 50 WYs from October 1, 1955, through September 30, 2005 (WY 1956 through WY 2005) were used to calculate total Delta inflow. These data include average daily inflows for all major streams entering the Delta and the total inflow into the Delta (DWR 2006).

The LPIII distribution was used to calculate return frequencies and confidence limits for TDI. These analyses resulted in 17 ranges of TDI and the probability that the annual peak daily inflow will be within a particular range. Estimates are provided for five different confidence limits, ranging from 5 percent confidence that the inflow will not be exceeded to 95 percent confidence that the inflow will not be exceeded. The estimated probabilities of an inflow being in each of the 17 ranges are given in Table 3-5 for each of the five confidence limits.

Inflow to the Delta comes from several sources, including the Yolo Bypass, Sacramento River, Cosumnes River, Mokelumne River, San Joaquin River, and other miscellaneous streams. The sum of these sources of inflow is TDI. Given the variability of flows in the streams making up the TDI, a large number of combinations of flows could account for any observed TDI. Logistic regression was used to estimate each tributary inflow. Regression coefficients were generated using the 50 years of measured inflow data. The logistic regression guarantees that the total flow from all the tributaries, even if randomly selected, will equal the TDI selected from the frequency distribution.

Table 5-1 presents the probabilities of a maximum tide on any given day. Tides are assumed to be independent of hydrologic events. Although this assumption may not be true for all hydrologic events, extreme tides are generally concurrent with a storm event, whereas the associated Delta inflow event occurs one to several days after the storm event.

Estimates of water surface elevations throughout the Delta associated with various inflow magnitudes, inflow patterns, and downstream tide levels are needed to estimate risks of levee failure due to overtopping and/or high water. Water surface elevations in the Delta were estimated from data on historical water levels measured at selected Delta gauging stations. Water levels, or stages, at the selected gauging stations were then used to interpolate stages at intermediate locations in the Delta. These data are reported using several different datums. All the data were converted to the NAVD88 datum before analysis.

Using the data on maximum daily tide, mean daily inflow, and measured stages at the gauging stations, multiple regression analyses were made for each of the stage-measuring stations. The regression analyses were made to determine best fit coefficients for Equations 7-1 and 7-2. Either Equation 7-1 or 7-2 was used in the regression analyses, depending on the stage measuring station being analyzed. Equation 7-1 was used to estimate stages at the Freeport (FTP) and Lisbon (LIS) stations because stages at these stations depend on flow in Sacramento River and Yolo Bypass respectively, and not the combined flows in Sacramento River and Yolo Bypass. Equation 7-2 was used for the other stage measuring stations because the measured stage better correlates with the combined Sacramento River and Yolo Bypass flows.

Future flood characteristics in the Delta were estimated using future daily flow estimates obtained from the climate change group. Two different climate models and two different climate change scenarios were used to estimate daily flows for the period 1951 to 2100. This provided four different 150-year records of daily flows. The climate models and climate change scenarios are described in *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1, Topical Area – Climate Change* (DWR 2007a) and the *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1, Topical Area – Water Analysis Module (WAM), Appendix F* (DWR 2007b).

A key assumption in using the synthetic runoff records to estimate probabilities of future inflows is:

> *The future change in frequency of a watershed event with a given current return frequency will produce the same future change in frequency for the Delta inflow of the same current return frequency.*

In other words, the shift in the frequency curve for the inflow to the Delta will be the same as the shift in the frequency curve for the watershed draining to the Delta. For example, if the 100-year event today in the watershed is a 50-year event in the future, then the 100-year inflow event into the Delta will be a 50-year event in the future. The synthetic data were analyzed to develop frequency distributions for three 50-year periods: year 2000, year 2050, and year 2100. These distributions were used calculate the change in frequency over time that was applied to the frequency distribution generated for the Total Delta Inflow. The methodologies, equations, and coefficients used to calculate inflow patterns are the same as for current hydrologic conditions. To estimate water surface elevations, an adjustment to account for sea level rise, and the associated reduction in hydraulic head loss for flows through the Delta, is needed. The method for making this adjustment is presented in Section 6.

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Tables

Table 2-1 PMF Estimates

	PMF Location	Area mi.2	PMF Estimates, cfs/mi.^{2}
	PMF Estimates By USBR		
1	Little Pinto Basin nr. Old Irontown, UT	0.30	9,967
2	Boney Branch nr. Rockport, MO	0.76	15,658
3	Dark Gulch nr. Glen Haven, CO	1.00	12,900
4	Headgate Draw nr. Buffalo, WY	1.10	10,091
5	Big Creek nr. Waynesville, NC	1.32	19,394
6	No. Fork Tributary, Big Thompson river nr. Glen Haven, CO	1.38	11,667
7	Stratton Creek nr. Washta, IA	1.90	6,947
8	Tributary to Dry Walnut Creek nr. Pawnee Rock, KS	2.28	6,316
9	Tributary to Kinneman Creek, ND	2.45	6,122
10	Travertine Creek nr. Sulphur, OK	3.00	8,300
11	South Fork Pine Canyon nr. Waterville, WA	4.50	6,222
12	Caney Creek nr. Eureka Springs, MS	4.90	8,204
13	Lane Canyon nr. Echo, OR	5.00	6,240
14	Brush Creek at 63d Street, Kansas City, MO	5.90	7,525
15	Round Grove Creek at Raytown Road Kansas City, MO	5.90	8,915
16	El Rancho Arroyo nr. Pajoaque, NM	6.70	7,493
17	Wayman Creek nr. Garber, IA	6.98	4,742
18	Molly Fork nr. Guernsey, WY	7.00	5,471
19	Boone Fork nr. Wilhurst, KY	7.40	6,446
20	Cass Draw nr. Carlsbad, NM	9.30	6,022
21	Nederlo Creek at Gays Mills, WI	9.46	3,953
22	Tig Trout Creek nr. Pickwick, MN	9.90	4,071
23	Trumansburg Creek nr. Trumansburg, NY	11.5	6,704
24	Meyers Canyon nr. Mitchell, OR	12.7	5,134
25	Brush Creek at Main Street, Kansas City, KS	14.8	6,128
26	Blieders Creek nr. New Braunfels, TX	15.0	5,413
27	Spring Creek nr. Fredericksburg, TX	15.2	6,086
28	Indian Wells Canyon nr. Inyokern, CA	16.6	4,747
29	Bronco Creek nr. Wickieup, AZ	19.0	5,195
30	Eldorado Canyon, NV	22.8	4,855
31	Bull Run nr. Catharpin, VA	25.8	4,217
32	Balm Creek nr. Heppner, OR	27.0	3,363
33	Percha Creek nr. Hillsboro, NM	35.4	3,831
34	Sergeant Major Creek nr. Cheyenne, OK	36.0	3,075
35	North Fork Hubbard Creek nr. Albany, TX	39.3	4,115
36	Otter Creek nr. Hanover, ND	42.9	1,944
37	North Fork Wahoo Creek nr. Weston, NE	43.7	2,023
38	Jimmy Camp Creek nr. Fountain, CO	54.0	3,537
39	Rapid Creek nr. Rapid City, SD	54.0	2,033
40	Wilson Creek nr. Adako, NC	66.0	2,848
41	North Prong Medina River nr. Medina, TX	67.5	2,996
42	Wewoka Creek nr. Lima, OK	75.0	2,276

Table 2-1 PMF Estimates

PMF Location		Area mi.2	PMF Estimates, cfs/mi.^{2}
PMF Estimates By USBR			
43	Mailtrail Draw nr. Loma Alta, TX	75.3	3,491
44	East Plum Creek nr. Castle Rick, CO	108	3,043
45	Whites Creek nr. Spring City, TN	108	3,407
46	Wild Horse Creek nr. Enid, OK	116	1,922
47	Arbuckle Dam nr. Sulphur, OK	126	3,032
48	Seco Creek nr. D'Hanis, TX	142	2,462
49	Little Nemaha River nr. Syracuse, NE	218	1,273
50	Middle Fork, Little Red River nr. Shirley, AR	302	1,054
51	Plum Creek nr. Louviers, CO	308	1,782
52	Two Medicine River nr. Browning, MT	317	626
53	Flint River nr. Chase, AL	342	761
54	Tye River nr. Norwood, VA	360	1,229
55	West Nueces River nr. Kickapoo Springs, TX	402	1,719
56	Santa Ana River nr. Riverside Narrows, CA	720	613
57	Bijou Creek nr. Wiggins, CO	1,380	529
58	So. Fork Republican River nr. Hale, CO	1,612	381
59	Neosho river nr. Strawn, KS	2,933	288
60	Pecos River nr. Comstock, TX	3,000	533
61	Eel River nr. Scotia, CA	3,113	319
PMF Estimates From the Internet			
1	Trinity Dam, CA	692	490
2	New Melones Dam, CA	904	164
3	Friant Dam, CA	1,650	348
4	Folsom Dam, CA	1,875	363
5	Shasta Dam, CA	6,665	93

Table 2-2 Partial List of Major Dams and Reservoirs in Tributary Watersheds to the San Francisco Bay-Delta

Dam Name	Watercourse	Tributary of	Reservoir	Year Original Construction Completed	Reservoir Capacity (acre-feet)
East Park	Little Stony Creek	Sacramento River	East Park	1910	
Daguerre Point	Yuba River	Sacramento River		1910	
Cache Creek	Cache Creek	Sacramento River	Clear Lake	1914	
Capay Diversion Dam	Cache Creek	Sacramento River		1914	
Stony Gorge	Stony Creek	Sacramento River	Stony Gorge	1928	
Pardee	Mokelumne River	San Joaquin River	Pardee	1929	210,000
Englebright	Yuba River	Sacramento River		1941	
Friant	San Joaquin River	San Joaquin River	Millerton Lake	1942	520,000
Shasta	Sacramento River	Sacramento River	Shasta Lake	1945	4,552,000
Martinez	off-stream storage		Martinez	1947	
Keswick	Sacramento River	Sacramento River	Keswick	1950	
Sly Park	Sly Park Creek	American / Sacramento River	Jenkinson Lake	1955	
Mormon Island Auxiliary Dam	Blue Ravine	American / Sacramento River	Folsom Lake	1956	
Folsom	American River	Sacramento River	Folsom Lake	1956	1,010,000
Tulloch	Stanislaus River	San Joaquin River	Tulloch	1957	68,000
Monticello	Putah Creek	Sacramento River	Lake Berryessa	1957	
Comanche	Mokelumne River	San Joaquin River	Comanche	1963	431,000
Whiskeytown	Clear Creek	Sacramento River	Whiskeytown Lake	1963	
Spring Creek Debris Dam	Spring Creek	Sacramento River	Spring Creek	1963	
Red Bluff (Diversion)	Sacramento River	Sacramento River	Lake Red Bluff	1964	
New Hogan	Calaveras River	San Joaquin River	New Hogan	1931, 1964	325,000
Los Banos (Detention)	Los Banos Creek	San Joaquin River	Los Banos	1965	
Little Panoche (Detention)	Little Panoche Creek	San Joaquin River	Little Panoche	1966	
San Luis	San Luis Creek	Delta - Mendota Canal	San Luis	1967	
O’Neill	San Luis Creek	Delta - Mendota Canal	O’Neill Forebay	1967	
Contra Loma	off-stream storage		Contra Loma	1967	
Oroville	Feather River	Sacramento River	Lake Oroville	1968	3,537,580
New Exchequer	Merced River	San Joaquin River	Lake McClure	1926, 1968	1,026,000
New Bullards Bar	Yuba River	Sacramento River	New Bullards Bar	1969	

Table 2-2 Partial List of Major Dams and Reservoirs in Tributary Watersheds to the San Francisco Bay-Delta

Dam Name	Watercourse	Tributary of	Reservoir	Year Original Construction Completed	Reservoir Capacity (acre-feet)
New Don Pedro	Tuolumne River	San Joaquin River	New Don Pedro	1923, 1971	2,030,000
Buchanan	Chowchilla River	San Joaquin River	Eastman Lake	1975	150,000
Indian Valley	N Fork Cache Creek	Sacramento River	Indian Valley	1976	300,600
New Melones	Stanislaus River	San Joaquin River	New Melones	1979	2,400,000
Sugar Pine	N Shirttail Creek	American / Sacramento River	Sugar Pine	1981	
Hidden	Fresno River	San Joaquin River	Hensley Lake		90,000
Almanor	N Fork Feather River	Sacramento River			

Table 2-3 Summary of Delta Inflows

Sacramento + Yolo Bypass Inflows	WY 1956 - 1968, pre-Oroville Dam	WY 1969 - 2005, ~Existing Conditions	WY 1956 - 2005, Period of Record
Average Daily Inflow, cfs	26,430	28,671	28,088
Avg. Annual Precip., inches[1]	17.4	18.1	18
Max. Annual Precip., inches	27.7	34.5	35
Inflow Range	**Number of Inflows in Q-Range**		
0-100K	4564	12924	17488
100K-200K	152	466	618
200K-300K	28	96	124
300K-400K	3	19	22
400K-500K	2	5	7
>500K	0	4	4
sum =	4749	13514	18263
Inflow Range	**No. of Days per Year With Inflows in Q-range**		
0-100K	351.1	349.3	349.8
100K-200K	11.7	12.6	12.4
200K-300K	2.2	2.6	2.5
300K-400K	0.2	0.5	0.4
400K-500K	0.2	0.1	0.1
>500K	0.0	0.1	0.1
sum =	365.3	365.2	365.3

San Joaquin River Inflows	WY 1956 - 1979, pre-New Melones Dam	WY 1980 - 2005, ~Existing Conditions	WY 1956 - 2005, Period of Record
Average Daily Inflow, cfs	4,416	4,809	4,416
Avg. Annual Precip., inches[2]	13.9	14.9	14.3
Max. Annual Precip., inches	25.9	27.5	27.5
Inflow Range	**Number of Inflows in Q-range**		
0-10K	8037	8270	16307
10K-20K	393	697	1090
20K-30K	247	336	583
30K-40K	74	171	245
40K-50K	15	22	37
>50K	0	1	1
sum =	8766	9497	18263
Inflow Range	**No. of Days per Year With Inflows in Q-range**		
0-10K	334.9	318.1	326.1
10K-20K	16.4	26.8	21.8
20K-30K	10.3	12.9	11.7
30K-40K	3.1	6.6	4.9
40K-50K	0.6	0.8	0.7
>50K	0.0	0.0	0.0
sum =	365.3	365.3	365.3

[1] Precipitation data from the Sacramento Airport, Station 47630.
[2] Friant Government Camp.

Table 2-4 Annual Peak Day Delta Inflows of Record (Water Years 1956 Through 2005)

Water Year	Date, WY Peak Inflow Day	Peak Day Sacramento River, cfs	Peak Day Yolo Bypass, cfs	Peak Day Cosumnes River, cfs	Peak Day Mokelumne River, cfs	Peak Day Misc. Streams, cfs	Peak Day San Joaquin River, cfs	Peak Day Total Inflow, cfs	Average 5-day Peak Inflow, cfs	Ratio: Avg. 5-day Peak to Peak Day	5-Day Inflow Vol. Up Through Peak Day, ac-ft
1986	February 20, 1986	113,000	499,301	15,600	4,490	14,981	13,900	661,272	551,714	0.83	4,501,390
1997	January 3, 1997	113,000	395,140	19,200	4,250	5,699	24,700	561,989	493,338	0.88	3,641,897
1965	December 25, 1964	98,600	343,265	11,500	150	2,607	14,000	470,122	382,948	0.81	2,673,209
1983	March 4, 1983	83,100	274,300	6,490	3,350	13,173	41,800	422,213	381,167	0.90	3,127,847
1995	March 13, 1995	96,100	266,562	6,340	2,440	1,635	14,100	387,177	336,016	0.87	2,229,884
1970	January 25, 1970	93,000	255,600	5,970	4,330	3,821	21,200	383,921	362,105	0.94	3,304,076
1956	December 23, 1955	90,200	249,600	34,100	2,180	4,032	3,210	383,322	276,247	0.72	1,571,520
1984	December 28, 1983	92,700	221,988	7,010	3,840	7,484	18,600	351,622	305,986	0.87	2,345,681
1963	February 2, 1963	94,400	230,107	17,300	3,260	1,962	3,830	350,859	202,799	0.58	1,190,319
1980	February 22, 1980	94,100	202,145	9,190	1,730	11,543	20,300	339,008	303,426	0.90	2,285,050
1998	February 8, 1998	86,800	193,521	6,130	2,930	7,331	26,300	323,012	305,585	0.95	2,823,322
1969	January 27, 1969	87,000	134,770	10,600	4,160	5,480	41,700	283,710	259,060	0.91	2,608,721
1958	February 26, 1958	85,500	174,510	6,140	1,650	3,276	7,750	278,826	245,784	0.88	2,281,874
1974	January 20, 1974	94,200	165,350	4,360	2,250	1,642	8,290	276,092	251,157	0.91	1,960,832
1982	February 17, 1982	98,000	103,742	11,700	3,030	14,203	7,720	238,395	175,241	0.74	1,041,400
1967	February 1, 1967	90,100	132,590	6,060	93	918	8,070	237,831	211,254	0.89	1,807,500
1973	January 19, 1973	92,700	112,559	6,790	1,910	2,472	6,370	222,801	196,152	0.88	1,728,843
1996	February 23, 1996	86,800	93,818	2,900	2,840	5,262	15,400	207,020	193,127	0.93	1,647,205
2004	February 28, 2004	73,800	105,288	1,500	326	1,050	4,220	186,184	177,486	0.95	1,594,217
1978	January 18, 1978	75,000	85,024	5,100	114	5,062	4,150	174,450	158,930	0.91	1,310,340
2000	February 28, 2000	81,700	63,375	5,010	2,010	3,071	13,600	168,766	156,851	0.93	1,446,424
1962	February 16, 1962	70,100	68,679	7,520	547	2,826	7,820	157,492	137,722	0.87	1,131,743
1993	March 28, 1993	82,300	53,026	3,280	431	662	3,950	143,649	136,829	0.95	1,300,621
1960	February 10, 1960	69,100	67,482	3,280	156	712	2,130	142,860	108,434	0.76	741,241
1999	February 11, 1999	85,400	31,150	3,630	2,770	6,568	11,900	141,418	124,608	0.88	991,787
1975	March 26, 1975	73,800	36,228	6,340	895	3,171	6,930	127,364	118,869	0.93	1,126,078

Table 2-4 Annual Peak Day Delta Inflows of Record (Water Years 1956 Through 2005)

Water Year	Date, WY Peak Inflow Day	Peak Day Sacramento River, cfs	Peak Day Yolo Bypass, cfs	Peak Day Cosumnes River, cfs	Peak Day Mokelumne River, cfs	Peak Day Misc. Streams, cfs	Peak Day San Joaquin River, cfs	Peak Day Total Inflow, cfs	Average 5-day Peak Inflow, cfs	Ratio: Avg. 5-day Peak to Peak Day	5-Day Inflow Vol. Up Through Peak Day, ac-ft
1957	March 7, 1957	79,200	36,361	4,050	1,800	1,024	4,690	127,125	112,424	0.88	959,768
1959	February 20, 1959	67,300	46,902	1,830	662	1,404	4,840	122,938	105,502	0.86	797,068
1971	December 5, 1970	73,200	32,983	5,880	1,230	1,675	3,640	118,608	108,748	0.92	923,631
2002	January 6, 2002	65,567	34,528	725	194	3,097	4,224	108,335	91,437	0.84	802,132
1979	February 24, 1979	71,300	5,170	2,660	1,260	7,856	12,800	101,046	95,445	0.94	838,080
2005	May 22, 2005	74,100	6,668	1,590	2,090	151	12,100	96,699	90,974	0.94	769,349
2003	January 3, 2003	65,300	25,560	261	211	154	2,280	93,766	83,057	0.89	751,934
1968	February 25, 1968	66,200	18,648	1,350	838	1,251	4,120	92,407	88,976	0.96	798,413
1989	March 27, 1989	73,500	26	1,820	7	11	2,020	77,384	68,450	0.88	578,604
1966	January 10, 1966	53,600	4,085	377	436	536	5,350	64,384	61,741	0.96	596,854
1981	January 31, 1981	51,900	5,096	759	72	741	5,700	64,268	60,686	0.94	525,396
1964	January 23, 1964	52,200	2,841	2,780	624	455	3,110	62,010	54,099	0.87	399,078
2001	March 9, 2001	46,200	4,425	483	289	627	5,660	57,684	53,441	0.93	505,557
1992	February 17, 1992	46,800	2,456	1,290	177	1,516	5,110	57,349	53,943	0.94	495,923
1991	March 27, 1991	46,900	3,260	1,310	119	2,027	3,310	56,926	49,859	0.88	398,339
1961	February 14, 1961	49,500	1,750	228	111	36	960	52,585	51,222	0.97	455,516
1985	November 30, 1984	41,200	3,408	511	762	439	3,500	49,820	47,470	0.95	461,516
1987	March 16, 1987	38,000	1,686	840	91	443	3,000	44,060	40,764	0.93	331,279
1988	January 7, 1988	37,200	3,245	203	46	49	1,280	42,023	39,287	0.93	291,814
1990	January 16, 1990	36,900	25	284	45	30	1,370	38,654	33,325	0.86	293,407
1972	December 28, 1971	31,100	192	1,440	96	406	3,430	36,664	35,424	0.97	337,839
1994	February 10, 1994	29,900	1,686	190	150	64	2,780	34,770	29,317	0.84	237,051
1976	December 8, 1975	30,600	48	53	297	15	3,580	34,593	33,457	0.97	325,369
1977	January 5, 1977	13,700	3	76	37	12	1,080	14,908	13,128	0.88	122,450

Table 3-1 Annual Peak Delta Inflows (cfs), 1956-2005

Water Year	Water Year Oct. 1 to Sept. 30	High Runoff Season Dec 16 to Apr 15	Low Runoff Season Oct 1 to Dec 15, Apr 16 to Sep 30
1956	383,322	383,322	80,086
1957	127,125	127,125	77,800
1958	278,826	278,826	127,867
1959	122,938	122,938	18,357
1960	142,860	142,860	21,479
1961	52,585	52,585	35,461
1962	157,492	157,492	35,160
1963	350,859	350,859	232,438
1964	62,010	62,010	42,188
1965	470,122	470,122	90,923
1966	64,384	64,384	38,415
1967	237,831	237,831	115,781
1968	92,407	92,407	25,433
1969	283,710	283,710	86,471
1970	383,921	383,921	26,488
1971	118,608	110,400	118,608
1972	36,664	36,664	22,654
1973	222,801	222,801	43,742
1974	276,092	276,092	123,106
1975	127,364	127,364	44,033
1976	34,593	30,651	34,593
1977	14,908	14,908	12,438
1978	174,450	174,450	70,752
1979	101,046	101,046	27,774
1980	339,008	339,008	33,394
1981	64,268	64,268	33,434
1982	238,395	238,395	197,768
1983	422,213	422,213	127,334
1984	351,622	351,622	169,189
1985	49,820	44,937	49,820
1986	661,272	661,272	48,018
1987	44,060	44,060	26,604
1988	42,023	42,023	28,941
1989	77,384	77,384	30,508
1990	38,654	38,654	23,052
1991	56,926	56,926	13,399
1992	57,349	57,349	13,870
1993	143,649	143,649	54,362
1994	34,770	34,770	29,893
1995	387,177	387,177	176,174
1996	207,020	207,020	98,021
1997	561,989	561,989	130,890
1998	323,012	323,012	112,420

Table 3-1 Annual Peak Delta Inflows (cfs), 1956-2005

Water Year	Water Year Oct. 1 to Sept. 30	High Runoff Season Dec 16 to Apr 15	Low Runoff Season Oct 1 to Dec 15, Apr 16 to Sep 30
1999	141,418	141,418	69,997
2000	168,766	168,766	43,293
2001	57,684	57,684	18,567
2002	108,335	108,335	39,772
2003	93,766	93,766	71,627
2004	186,184	186,184	34,270
2005	96,699	73,956	96,699

Table 3-2 Results of Log Pearson Type III Frequency Analyses

Probability	Inflows For Various Percent Confidence That The Inflow Will Not Be Exceeded												
	CL = 99%	CL = 97.5%	CL = 95%	CL = 90%	CL = 80%	CL = 60%	CL = 50%	CL = 40%	CL = 20%	CL = 10%	CL = 5%	CL = 2.5%	CL = 1%
All Seasons Inflow													
0.5000	183,628	174,123	167,003	159,301	150,600	139,862	135,551	131,292	121,982	115,391	110,149	105,728	100,438
0.2000	417,743	384,177	362,404	340,001	316,076	288,481	280,047	267,913	246,965	232,973	222,322	213,661	205,125
0.1000	646,984	583,006	543,290	503,306	461,634	414,947	402,011	381,158	347,674	325,861	309,564	296,514	284,711
0.0500	925,781	819,574	755,468	691,963	626,943	555,619	536,997	505,080	455,965	424,523	401,337	382,966	367,245
0.0400	1,026,698	904,163	830,738	758,322	684,543	604,074	583,366	547,383	492,578	457,658	431,996	411,722	394,606
0.0250	1,257,855	1,096,264	1,000,731	907,312	813,021	711,305	685,788	640,424	572,582	529,736	498,454	473,871	453,614
0.0200	1,376,716	1,194,262	1,087,010	982,520	877,483	764,716	736,715	686,503	611,966	565,071	530,929	504,158	482,312
0.0100	1,784,960	1,527,536	1,378,571	1,234,957	1,092,240	941,059	904,505	837,586	740,151	679,497	635,677	601,532	574,362
0.0050	2,255,260	1,906,317	1,707,080	1,516,767	1,329,544	1,133,535	1,087,120	1,000,928	877,353	801,129	746,428	704,032	670,944
0.0020	2,978,735	2,480,798	2,200,802	1,936,227	1,679,002	1,413,366	1,351,820	1,236,059	1,072,812	973,177	902,221	847,564	805,745
0.0010	3,607,958	2,974,111	2,621,311	2,290,391	1,971,236	1,644,691	1,570,048	1,428,709	1,231,467	1,111,939	1,027,254	962,289	913,176
0.0005	4,312,097	3,520,576	3,084,102	2,677,476	2,288,198	1,893,304	1,804,086	1,634,300	1,399,532	1,258,192	1,158,523	1,082,350	1,025,346
0.0001	6,257,320	5,006,780	4,330,189	3,708,698	3,122,771	2,538,809	2,409,770	2,162,386	1,826,400	1,626,823	1,487,440	1,381,729	1,304,080
High Inflow Season													
0.5000	181,568	172,677	165,544	157,831	149,124	138,385	134,031	129,820	120,522	113,944	108,714	104,307	99,311
0.2000	413,058	384,136	362,145	339,533	315,401	287,591	276,906	266,882	245,805	231,739	221,037	212,338	202,824
0.1000	639,727	585,479	545,194	504,669	462,468	415,235	397,502	381,085	347,276	325,268	308,836	295,684	281,518
0.0500	915,397	825,972	760,721	696,137	630,079	557,696	530,974	506,465	456,730	424,919	401,476	382,913	363,125
0.0400	1,015,182	912,153	837,341	763,625	688,596	606,861	576,822	549,344	493,801	458,443	432,477	411,975	390,180
0.0250	1,243,746	1,108,170	1,010,641	915,363	819,299	715,802	678,096	643,769	574,902	531,453	499,753	474,855	448,526
0.0200	1,361,275	1,208,309	1,098,719	992,060	884,962	770,130	728,451	690,588	614,872	567,283	532,662	505,531	476,903
0.0100	1,764,939	1,549,465	1,396,870	1,249,918	1,104,061	949,770	894,360	844,316	745,139	683,467	638,948	604,280	567,919
0.0050	2,229,964	1,938,146	1,733,590	1,538,429	1,346,685	1,146,245	1,074,926	1,010,841	884,829	807,192	751,524	708,407	663,418
0.0020	2,945,324	2,529,142	2,240,895	1,968,875	1,704,783	1,432,499	1,336,657	1,251,046	1,084,220	982,528	910,174	854,479	796,708
0.0010	3,567,490	3,037,795	2,673,925	2,333,085	2,004,848	1,669,586	1,552,438	1,448,212	1,246,349	1,124,182	1,037,709	971,422	902,933
0.0005	4,263,731	3,602,278	3,151,331	2,731,820	2,330,828	1,924,779	1,783,850	1,658,929	1,418,332	1,273,682	1,171,779	1,093,960	1,013,845
0.0001	6,187,136	5,141,778	4,440,231	3,796,821	3,191,257	2,588,905	2,382,741	2,201,376	1,856,069	1,651,259	1,508,377	1,400,104	1,289,453

Table 3-2 Results of Log Pearson Type III Frequency Analyses

Probability	Inflows For Various Percent Confidence That The Inflow Will Not Be Exceeded												
	CL = 99%	CL = 97.5%	CL = 95%	CL = 90%	CL = 80%	CL = 60%	CL = 50%	CL = 40%	CL = 20%	CL = 10%	CL = 5%	CL = 2.5%	CL = 1%
Low Inflow Season													
0.5000	68,727	65,878	63,574	61,061	58,198	54,623	53,160	51,736	48,561	46,287	44,462	42,911	41,138
0.2000	139,955	131,575	125,144	118,473	111,284	102,898	99,645	96,576	90,066	85,675	82,306	79,549	76,513
0.1000	207,931	192,620	181,139	169,485	157,226	143,338	138,074	133,174	122,995	116,301	111,264	107,208	102,812
0.0500	290,229	265,260	246,858	228,475	209,477	188,403	180,547	173,303	158,476	148,897	141,785	136,120	130,045
0.0400	320,067	291,342	270,273	249,319	227,768	204,001	195,181	187,069	170,532	159,899	152,032	145,783	139,102
0.0250	388,659	350,886	323,437	296,368	268,789	238,708	227,642	217,513	197,019	183,960	174,362	166,780	158,715
0.0200	424,091	381,448	350,586	320,264	289,499	256,103	243,863	232,684	210,139	195,828	185,340	177,074	168,302
0.0100	546,819	486,453	443,268	401,289	359,189	314,108	297,761	282,918	253,258	234,632	221,091	210,485	199,300
0.0050	690,367	607,903	549,521	493,307	437,513	378,485	357,283	338,130	300,165	276,549	259,496	246,215	232,282
0.0020	916,000	796,528	712,991	633,460	555,491	474,173	445,288	419,355	368,429	337,098	314,656	297,288	279,181
0.0010	1,117,030	962,759	855,816	754,796	656,598	555,188	519,441	487,483	425,124	387,048	359,923	339,023	317,321
0.0005	1,347,193	1,151,399	1,016,766	890,518	768,770	644,191	600,590	561,764	486,453	440,790	408,423	383,584	357,892
0.0001	1,999,908	1,678,991	1,462,024	1,261,661	1,071,627	880,862	815,089	756,991	645,681	579,164	532,504	496,990	460,544

CL = confidence limit

Table 3-3 Parameters Used in Log Pearson Type III Distribution

Season	Mean	Standard Deviation	Skew	Weighted Slew
All	5.12	0.383	-0.188	-0.219
High	5.11	0.387	-0.184	-0.216
Low	4.72	0.325	0.0645	-0.0323

Weighted skew is a function of the generalized skew (-0.3000) and Mean Square Error of Generalized Skew (see p. 13, of Bulletin 17B)

Table 3-4 PMF Inflows into the Delta

Confidence Limits:		PMF Values For Delta, Area (mi.2) = 42,460
%	**K**	
1%	-2.32634	1,799,962
2.5%	-1.95996	2,083,139
5%	-1.64485	2,362,072
10%	-1.28155	2,730,328
20%	-0.84162	3,253,928
40%	-0.25335	4,114,277
50%	0.00000	4,551,679
60%	*0.25335*	5,035,583
80%	0.84162	6,367,007
90%	1.28155	7,588,020
95%	1.64485	8,771,022
97.5%	1.95996	9,945,463
99%	*2.32634*	11,510,122

Table 3-5 Inflow Ranges (Bins) and Confidence Limit Probabilities For The High Inflow Season - Year 2000

						50% Confidence Limit		80% Confidence Limit		20% Confidence Limit		95% Confidence Limit		5% Confidence Limit	
Bin #	LN (Lower Value)	LN (Upper Value)	Lower Value	Upper Value	Designated Bin Value[1]	Proabability of Exceedance	Probability of Being in Bin	Proabability of Exceedance	Probability of Being in Bin	Proabability of Exceedance	Probability of Being in Bin	Proabability of Exceedance	Probability of Being in Bin	Proabability of Exceedance	Probability of Being in Bin
			0	30,045		1.000		1.000		1.000		1.000		1.000	
1	10.310438	10.581243	30,045	39,389	34,717	0.940	0.060	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
2	10.581243	10.852048	39,389	51,640	45,514	0.865	0.072	0.970	0.030	1.000	0.010	1.000	0.000	0.970	0.030
3	10.852048	11.122853	51,640	67,701	59,670	0.780	0.084	0.911	0.059	1.000	0.025	1.000	0.000	0.920	0.050
4	11.122853	11.393658	67,701	88,757	78,229	0.685	0.095	0.817	0.094	0.900	0.060	0.830	0.100	0.840	0.080
5	11.393658	11.664463	88,757	116,362	102,560	0.565	0.105	0.673	0.144	0.800	0.100	0.680	0.150	0.735	0.105
6	11.664463	11.935268	116,362	152,553	134,458	0.445	0.113	0.498	0.175	0.650	0.154	0.530	0.220	0.617	0.118
7	11.935268	12.206073	152,553	200000	176,277	0.353	0.121	0.299	0.190	0.402	0.174	0.248	0.220	0.490	0.127
8	12.206073	12.476878	200,000	262,204	231,102	0.225	0.120	0.174	0.125	0.284	0.180	0.138	0.150	0.360	0.130
9	12.476878	12.747683	262,204	343,754	302,979	0.130	0.095	0.103	0.080	0.168	0.116	0.078	0.082	0.235	0.125
10	12.747683	13.018488	343,754	450,669	397,212	0.076	0.060	0.053	0.051	0.106	0.075	0.036	0.042	0.145	0.090
11	13.018488	13.289293	450,669	590,835	520,752	0.038	0.038	0.023	0.030	0.060	0.046	0.014	0.022	0.085	0.060
12	13.289293	13.560098	590,835	774,597	682,716	0.017	0.021	0.009	0.014	0.030	0.030	0.004	0.010	0.047	0.038
13	13.560098	13.830903	774,597	1,015,511	895,054	0.006	0.011	0.003	0.006	0.014	0.016	0.001	0.003	0.025	0.023
14	13.830903	14.101708	1,015,511	1,331,355	1,173,433	0.002	0.004	0.001	0.002	0.005	0.008	0.0002460	0.001	0.012	0.013
15	14.101708	14.372513	1,331,355	1,745,432	1,538,394	0.001	0.002	0.000	0.001	0.002	0.003	0.0000415	0.000	0.005	0.007
16	14.372513	14.643318	1,745,432	2,288,296	2,016,864	0.000	0.000	0.000	0.000	0.001	0.001	0.0000044	0.000	0.002	0.003
17	14.643318	14.914123	2,288,296	3,000,000	2,644,148	0.000	0.000	0.000	0.000	0.000	0.000	0.0000005	0.000	0.001	0.001
						Totals =	**1.000**		**1.000**		**0.9994**		**0.9998**		**0.9994**

[1] Designated Bin Value is average of Lower & Upper Value.

Table 4-1 Summary of Data Used for Flow Pattern Analysis for Inflows to Delta

Statistic/Delta Inflow	SAC	YOLO	CSMR	MOKE	MISC	SJR	Total
Average	86,718	147,538	6,865	3,361	5,787	23,991	274,261
Standard Deviation	7,294	68,429	6,555	1,520	4,326	11,882	75,245
Coefficient of Variation	0.084	0.46	0.95	0.45	0.74	0.49	0.27
1st Quartile	81,200	100,739	3,260	2,810	3,000	14,950	221,723
2nd Quartile (median)	86,100	131,803	4,830	3,380	4,804	22,900	253,531
3rd Quartile	91,750	174,671	7,800	4,365	7,553	33,650	303,439
Minimum	69,400	58,449	1,200	57	146	1,450	200,568
Maximum	115,000	499,301	53,600	14,200	30,532	54,300	661,272
Number of data points	251	251	251	251	251	251	251

Table 4-2 Results of Logistic Regressions

River	a (Slope)	b (Intercept)	r^2	Standard Error of Regression
Sacramento + Yolo Bypass	.563	-5.21	0.054	0.530
San Joaquin River	0.430	-4.173	0.075	0.709
Miscellaneous Flows	0.379	-4.453	0.071	0.665
Cosumnes River	1.116	-9.670	0.358	0.714

Table 4-3 Comparison Between Observed and Predicted Flows in Delta Inflows

	Statistic	Yolo ByPass	Sacramento River	San Joaquin River	Miscellaneous Flows	Cosumnes River	Mokelumne River
Average	Observed	147,538	86,718	23,991	5,787	6,865	3,361
	Predicted	150,213	86,877	21,898	5,329	6,436	3,507
	Percent Error	-1.81	-0.18	8.72	7.90	6.25	4.35
Median	Observed	131,803	86,100	22,900	4,804	4,830	3,380
	Predicted	131,736	85,779	21,074	5,179	6,270	3,494
	Percent Error	0.05	0.37	7.98	-7.80	-29.82	-3.38

Table 5-1 Probability of San Francisco Tide Elevation, High Delta Inflow Season

Bin No.	Max. Bin Tide, feet	Min. Bin Tide, feet	Avg. Bin Tide, feet	Probability Of Occurrence High Inflow Season	Probability Of Exceedance High Inflow Season
1	3.75	4.00	3.875	0.0005	0.9995
2	4.00	4.25	4.125	0.0015	0.9980
3	4.25	4.50	4.375	0.0044	0.9936
4	4.50	4.75	4.625	0.0184	0.9752
5	4.75	5.00	4.875	0.0444	0.9308
6	5.00	5.25	5.125	0.0877	0.8431
7	5.25	5.50	5.375	0.1243	0.7188
8	5.50	5.75	5.625	0.1548	0.5640
9	5.75	6.00	5.875	0.1410	0.4230
10	6.00	6.25	6.125	0.1360	0.2870
11	6.25	6.50	6.375	0.1072	0.1798
12	6.50	6.75	6.625	0.0738	0.1059
13	6.75	7.00	6.875	0.0487	0.0572
14	7.00	7.25	7.125	0.0293	0.0280
15	7.25	7.50	7.375	0.0145	0.0135
16	7.50	7.75	7.625	0.0067	0.0067
17	7.75	8.00	7.875	0.0041	0.0026
18	8.00	8.25	8.125	0.0018	0.0008
19	8.25	8.50	8.375	0.0003	0.0005
20	8.50	8.75	8.625	0.0003	0.0002
21	8.75	9.00	8.875	0.0000	0.0002
22	9.00	9.25	9.125	0.0002	0.0000

Table 5-2 Elevation Adjustment to Account for August Inflow into the Delta

Station Name	Number of August Tide Cycles Used In Calculations	Mean August Stage @ Delta Station, feet NAVD 88 Datum	August MSL @ Golden Gate, feet NAVD 88 Datum	Elevation Difference Due to August Delta Inflow, feet	Hydraulic Gradient x10^{-5} to Mallard Gauging Station (MAL)
Western Delta					
BDL	3	4.02	3.38	0.64	0.20
ROR	5	4.04	3.33	0.71	0.57
MAL	4	3.91	3.37	0.54	N/A
North Central Delta					
BEN	5	5.59	3.31	2.29	0.66
GSS	3	5.11	3.38	1.73	0.76
North Delta					
FPT	5	6.73	3.26	3.47	1.29
SSS	2	6.36	3.33	3.03	1.69
LIS	4	5.66	3.27	2.39	0.88
South Delta – Middle River					
MTB	4	5.01	3.37	1.64	0.45
MHR	3	5.28	3.38	1.90	0.50
South Delta – Old River					
OLD	5	4.78	3.25	1.53	0.45
ORB	5	4.56	3.35	1.21	0.44
BAC	5	4.80	3.33	1.47	0.81
Southeast Delta – San Joaquin River					
SJL	3	5.39	3.31	2.09	0.75
VNI	5	4.30	3.27	1.03	0.31

Table 5-3 Station Adjustments to Obtain NAVD 88 Datum

Station Name	Avg. Aug. Stage @ Station, feet	Avg. Aug. MSL @ Golden Gate, feet	Difference, Aug. MSL @ Golden Gate minus Aug. Stage @ Station, feet	Stage Adjustment for August Inflows, feet	Total Station Adjustment for NAVD 88 Datum, feet
Western Delta					
BDL	4.02	3.38	0.64	0.64	0.00
ROR	4.04	3.33	0.71	0.71	0.00
MAL	1.40	3.91	-1.98	0.54	2.51
North Central Delta					
BEN	5.59	3.31	2.29	2.29	0.00
GSS	5.11	3.38	1.73	1.73	0.00
North Delta					
FPT	4.26[1]	3.26	1.00	3.47	2.47
SSS	3.93	3.33	0.61	3.04	2.43
LIS	5.66	3.27	2.39	2.39	0.00
South Delta – Middle River					
MTB	5.01	3.37	1.64	1.64	0.00
MHR	5.28	3.38	1.90	1.90	0.00
South Delta – Old River					
OLD	4.78	3.25	1.53	1.53	0.00
ORB	4.56	3.35	1.21	1.21	0.00
BAC	4.71	3.33	1.38	1.38	0.00
Southeast Delta – San Joaquin River					
SJL	5.39	3.37	2.02	2.02	0.00
VNI	5.02	3.27	1.75	1.75	0.00

Note: Measured stage at Freeport (FPT) has been adjusted by 100 feet.

Table 5-4 Estimated Coefficients "a" Through "g" in Equations 5-1 and 5-2

Station ID	Coefficients							Samples Used	Avg. Error[1]	Avg. Abs. Error	Max Abs. Error
	a	b	c	d	e	f	g				
West Delta											
MAL	0.91	0.000247	NA	0.000363	0.000385	0.000000	0.000000	730	0.00	0.02	0.93
BDL	1.00	0.000123	NA	0.000696	0.000566	0.000000	0.000102	205	0.00	0.16	0.57
ROR	0.94	0.000302	NA	0.000148	0.000337	0.000000	0.000001	373	0.00	0.29	1.35
North Central Delta											
BEN	0.38	0.002020	0.000047	0.000750	0.013245	0.010418	0.006022	684	0.00	0.74	5.34
GSS	0.34	0.005067	0.000201	0.000000	0.000000	0.007334	0.000000	52	0.00	0.11	0.56
North Delta											
FPT	0.00	0.009705	0.000520	0.000000	0.001266	0.001466	0.000660	783	0.00	0.45	2.00
SSS	0.19	0.006071	0.000162	0.000003	0.000368	0.003880	0.000000	56	0.00	0.15	0.47
LIS	0.67	0.004997	0.001708	0.002487	0.000000	0.000000	0.000000	129	0.00	0.91	6.94
South Delta – Middle River											
MHR	0.88	0.000431	NA	0.002279	0.002543	0.000000	0.000000	105	0.00	0.21	0.21
MTB	0.90	0.000312	NA	0.001652	0.001220	0.000000	0.000000	123	0.00	0.22	1.21
South Delta – Old River											
OLD	0.81	0.000294	NA	0.002717	0.002480	0.000000	0.000000	85	0.00	0.24	1.05
BAC	1.00	0.000306	NA	0.000113	0.003236	0.000000	0.000000	100	0.00	0.32	1.35
ORB	0.79	0.000531	NA	0.001602	0.002982	0.001474	0.000000	109	0.00	0.20	0.77
Southeast Delta – San Joaquin River											
SJL	0.77	0.000181	NA	0.009743	0.001596	0.000000	0.000000	99	0.00	0.29	1.14
VNI	0.97	0.000387	NA	0.000925	0.000328	0.000000	0.000000	477	0.00	0.17	0.58

Table 6-1 Probabilities: Future Climate Scenarios

7-Day Total Watershed Runoff	Probability of Exceedance, Year 2000	Probability of Exceedance, Year 2025	Probability of Exceedance, Year 2050	Probability of Exceedance, Year 2075	Probability of Exceedance, Year 2100 (Extrapolated)
Climate Scenario Sresb1-gfdl, 50% Confidence Limit					
1,362,410	0.50000	0.38107	0.49500	0.49500	0.49500
2,487,932	0.20000	0.17814	0.21000	0.22000	0.23000
3,376,047	0.10000	0.09776	0.11500	0.11800	0.12100
4,322,867	0.05000	0.05156	0.06500	0.07000	0.07500
4,641,862	0.04000	0.04157	0.05500	0.06000	0.06500
5,337,778	0.02500	0.02597	0.03570	0.04050	0.04530
5,679,954	0.02000	0.02061	0.02800	0.03400	0.04000
6,793,140	0.01000	0.00972	0.01650	0.01980	0.02310
7,985,137	0.00500	0.00434	0.00900	0.01200	0.01500
9,687,205	0.00200	0.00138	0.00415	0.00560	0.00705
11,073,852	0.00100	0.00054	0.00240	0.00360	0.00480
12,548,689	0.00050	0.00020	0.00130	0.00198	0.00266
16,326,850	0.00010	0.00002	0.00039	0.00056	0.00074
Climate Scenario Sresb1-ncar, 50% Confidence Limit					
1,265,807	0.50000	0.40677	0.58000	0.60000	0.62000
2,284,426	0.20000	0.20439	0.37000	0.42000	0.47000
3,059,426	0.10000	0.12108	0.23000	0.30800	0.38600
3,861,594	0.05000	0.07042	0.14500	0.20000	0.25500
4,126,830	0.04000	0.05887	0.12800	0.17500	0.22200
4,697,370	0.02500	0.04004	0.10000	0.14000	0.18000
4,974,095	0.02000	0.03321	0.08800	0.12700	0.16600
5,858,156	0.01000	0.01827	0.06000	0.09200	0.12400
6,779,960	0.00500	0.00980	0.04000	0.07000	0.10000
8,056,907	0.00200	0.00414	0.02350	0.04500	0.06650
9,066,883	0.00100	0.00209	0.01650	0.03500	0.05350
10,114,551	0.00050	0.00103	0.01100	0.02500	0.03900
12,689,828	0.00010	0.00018	0.00450	0.01280	0.02110
Climate Scenario Sresa2-gfdl, 50% Confidence Limit					
1,313,882	0.50000	0.39377	0.54000	0.48000	0.42000
2,411,546	0.20000	0.18757	0.28000	0.23000	0.18000
3,252,967	0.10000	0.10624	0.14700	0.13000	0.11300
4,126,932	0.05000	0.05886	0.08500	0.08000	0.07500
4,416,364	0.04000	0.04841	0.07173	0.06823	0.06474
5,039,498	0.02500	0.03177	0.05198	0.05230	0.05263
5,341,945	0.02000	0.02590	0.04445	0.04597	0.04748
6,308,805	0.01000	0.01348	0.02697	0.03043	0.03388
7,317,531	0.00500	0.00682	0.01601	0.01978	0.02355
8,715,140	0.00200	0.00265	0.00777	0.01090	0.01402
9,820,289	0.00100	0.00126	0.00439	0.00680	0.00921
10,966,159	0.00050	0.00058	0.00243	0.00417	0.00591

Table 6-1 Probabilities: Future Climate Scenarios

7-Day Total Watershed Runoff	Probability of Exceedance, Year 2000	Probability of Exceedance, Year 2025	Probability of Exceedance, Year 2050	Probability of Exceedance, Year 2075	Probability of Exceedance, Year 2100 (Extrapolated)
13,779,367	0.00010	0.00009	0.00057	0.00125	0.00194
Climate Scenario Sresa2-ncar, 50% Confidence Limit					
1,255,258	0.50000	0.40968	0.60000	0.60000	0.60000
2,354,395	0.20000	0.19495	0.29000	0.33500	0.38000
3,245,910	0.10000	0.10674	0.13200	0.17500	0.21800
4,215,011	0.05000	0.05546	0.07000	0.10750	0.14500
4,545,318	0.04000	0.04437	0.06500	0.08970	0.11440
5,271,974	0.02500	0.02716	0.03400	0.06350	0.09300
5,632,110	0.02000	0.02129	0.02700	0.05270	0.07840
6,815,802	0.01000	0.00957	0.01350	0.03080	0.04810
8,101,898	0.00500	0.00401	0.00610	0.01780	0.02950
9,968,069	0.00200	0.00114	0.00240	0.00810	0.01380
11,511,655	0.00100	0.00040	0.00110	0.00480	0.00850
13,174,150	0.00050	0.00013	0.00051	0.00280	0.00509
17,520,125	0.00010	0.00001	0.00007	0.00075	0.00143

Table 6-2: Delta Inflow Probabilities

Climate Scenario Sresb1-gfdl

Discharge, cfs	Probability of Exceedance, Year 2000	Probability of Exceedance, Year 2050	Probability of Exceedance, Year 2100
Confidence Limit = 95%			
165,544	0.50000	0.49000	0.50000
362,145	0.20000	0.22000	0.24600
545,194	0.10000	0.11800	0.13200
760,721	0.05000	0.06600	0.08400
837,341	0.04000	0.05500	0.07200
1,010,641	0.02500	0.03600	0.04800
1,098,719	0.02000	0.03100	0.03900
1,396,870	0.01000	0.01700	0.02400
1,733,590	0.00500	0.00940	0.01560
2,240,895	0.00200	0.00435	0.00765
2,673,925	0.00100	0.00250	0.00480
3,151,331	0.00050	0.00130	0.00300
4,440,231	0.00010	0.00040	0.00064
Confidence Limit = 80%			
149,124	0.50000	0.49000	0.50000
315,401	0.20000	0.21500	0.24500
462,468	0.10000	0.11500	0.12500
630,079	0.05000	0.07000	0.08600
688,596	0.04000	0.05350	0.06950
819,299	0.02500	0.03600	0.04500
884,962	0.02000	0.03000	0.04000
1,104,061	0.01000	0.01700	0.02300
1,346,685	0.00500	0.00910	0.01530
1,704,783	0.00200	0.00435	0.00765
2,004,848	0.00100	0.00240	0.00470
2,330,828	0.00050	0.00130	0.00270
3,191,257	0.00010	0.00039	0.00071
Confidence Limit = 50%			
134,031	0.50000	0.49500	0.49500
276,906	0.20000	0.21000	0.23000
397,502	0.10000	0.11500	0.12100
530,974	0.05000	0.06500	0.07500
576,822	0.04000	0.05500	0.06500
678,096	0.02500	0.03570	0.04530
728,451	0.02000	0.02800	0.04000
894,360	0.01000	0.01650	0.02310
1,074,926	0.00500	0.00900	0.01500
1,336,657	0.00200	0.00415	0.00705
1,552,438	0.00100	0.00240	0.00480
1,783,850	0.00050	0.00130	0.00266
2,382,741	0.00010	0.00039	0.00074
Confidence Limit = 20%			
120,522	0.50000	0.48000	0.48000
245,805	0.20000	0.21000	0.22000
347,276	0.10000	0.11000	0.13000
456,730	0.05000	0.06100	0.07900
493,801	0.04000	0.05000	0.07000
574,902	0.02500	0.03500	0.04300
614,872	0.02000	0.02750	0.03750
745,139	0.01000	0.01600	0.02200
884,829	0.00500	0.00850	0.01350
1,084,220	0.00200	0.00400	0.00720
1,246,349	0.00100	0.00235	0.00425
1,418,332	0.00050	0.00125	0.00235
1,856,069	0.00010	0.00040	0.00110
Confidence Limit = 5%			
108,714	0.50000	0.49000	0.45000
221,037	0.20000	0.20500	0.20500
308,836	0.10000	0.11000	0.12000
401,476	0.05000	0.06000	0.07000
432,477	0.04000	0.05000	0.06000
499,753	0.02500	0.03450	0.04150
532,662	0.02000	0.02850	0.03550
638,948	0.01000	0.01530	0.02170
751,524	0.00500	0.00820	0.01280
910,174	0.00200	0.00400	0.00700
1,037,709	0.00100	0.00230	0.00370
1,171,779	0.00050	0.00120	0.00240
1,508,377	0.00010	0.00036	0.00074

Climate Scenario Sresb1-ncar

Discharge, cfs	Probability of Exceedance, Year 2000	Probability of Exceedance, Year 2050	Probability of Exceedance, Year 2100
Confidence Limit = 95%			
165,544	0.50000	0.58000	0.66000
362,145	0.20000	0.37800	0.48200
545,194	0.10000	0.23500	0.39100
760,721	0.05000	0.14100	0.26300
837,341	0.04000	0.12800	0.22600
1,010,641	0.02500	0.09800	0.17600
1,098,719	0.02000	0.08500	0.16500
1,396,870	0.01000	0.06000	0.12000
1,733,590	0.00500	0.03900	0.09700
2,240,895	0.00200	0.02170	0.06030
2,673,925	0.00100	0.01580	0.04920
3,151,331	0.00050	0.01030	0.03570
4,440,231	0.00010	0.00420	0.01940
Confidence Limit = 80%			
149,124	0.50000	0.59000	0.61000
315,401	0.20000	0.37300	0.47700
462,468	0.10000	0.23500	0.38500
630,079	0.05000	0.14000	0.26000
688,596	0.04000	0.12500	0.23100
819,299	0.02500	0.10000	0.17800
884,962	0.02000	0.08500	0.16100
1,104,061	0.01000	0.05900	0.13100
1,346,685	0.00500	0.03900	0.10100
1,704,783	0.00200	0.02300	0.06100
2,004,848	0.00100	0.01610	0.04790
2,330,828	0.00050	0.01060	0.03340
3,191,257	0.00010	0.00430	0.02070
Confidence Limit = 50%			
134,031	0.50000	0.58000	0.62000
276,906	0.20000	0.37000	0.47000
397,502	0.10000	0.23000	0.38600
530,974	0.05000	0.14500	0.25500
576,822	0.04000	0.12800	0.22200
678,096	0.02500	0.10000	0.18000
728,451	0.02000	0.08800	0.16600
894,360	0.01000	0.06000	0.12400
1,074,926	0.00500	0.04000	0.10000
1,336,657	0.00200	0.02350	0.06650
1,552,438	0.00100	0.01650	0.05350
1,783,850	0.00050	0.01100	0.03900
2,382,741	0.00010	0.00450	0.02110
Confidence Limit = 20%			
120,522	0.50000	0.58000	0.60000
245,805	0.20000	0.36000	0.47000
347,276	0.10000	0.22700	0.37700
456,730	0.05000	0.14000	0.25000
493,801	0.04000	0.12500	0.22500
574,902	0.02500	0.10000	0.18000
614,872	0.02000	0.08500	0.16900
745,139	0.01000	0.06000	0.13000
884,829	0.00500	0.04000	0.10000
1,084,220	0.00200	0.02400	0.06600
1,246,349	0.00100	0.01700	0.05300
1,418,332	0.00050	0.01120	0.04080
1,856,069	0.00010	0.00465	0.02175
Confidence Limit = 5%			
108,714	0.50000	0.58000	0.60000
221,037	0.20000	0.36000	0.45000
308,836	0.10000	0.22700	0.35300
401,476	0.05000	0.14000	0.24600
432,477	0.04000	0.12510	0.22090
499,753	0.02500	0.09950	0.17850
532,662	0.02000	0.08700	0.16300
638,948	0.01000	0.05950	0.13050
751,524	0.00500	0.04000	0.10000
910,174	0.00200	0.02400	0.06600
1,037,709	0.00100	0.01700	0.05340
1,171,779	0.00050	0.01140	0.04020
1,508,377	0.00010	0.00470	0.02170

Climate Scenario Sresa2-gfdl

Discharge, cfs	Probability of Exceedance, Year 2000	Probability of Exceedance, Year 2050	Probability of Exceedance, Year 2100
Confidence Limit = 95%			
165,544	0.50000	0.54000	0.46000
362,145	0.20000	0.28000	0.22000
545,194	0.10000	0.14000	0.13000
760,721	0.05000	0.08200	0.08800
837,341	0.04000	0.06986	0.07012
1,010,641	0.02500	0.05229	0.05964
1,098,719	0.02000	0.04532	0.05491
1,396,870	0.01000	0.02838	0.04145
1,733,590	0.00500	0.01716	0.03019
2,240,895	0.00200	0.00836	0.01881
2,673,925	0.00100	0.00465	0.01264
3,151,331	0.00050	0.00250	0.00821
4,440,231	0.00010	0.00052	0.00266
Confidence Limit = 80%			
149,124	0.50000	0.54000	0.44000
315,401	0.20000	0.28500	0.20500
462,468	0.10000	0.14200	0.12400
630,079	0.05000	0.08300	0.08100
688,596	0.04000	0.07105	0.06823
819,299	0.02500	0.05227	0.05668
884,962	0.02000	0.04498	0.05163
1,104,061	0.01000	0.02768	0.03783
1,346,685	0.00500	0.01656	0.02687
1,704,783	0.00200	0.00804	0.01633
2,004,848	0.00100	0.00451	0.01083
2,330,828	0.00050	0.00246	0.00698
3,191,257	0.00010	0.00054	0.00227
Confidence Limit = 50%			
134,031	0.50000	0.54000	0.42000
276,906	0.20000	0.28000	0.18000
397,502	0.10000	0.14700	0.11300
530,974	0.05000	0.08500	0.07500
576,822	0.04000	0.07173	0.06474
678,096	0.02500	0.05198	0.05263
728,451	0.02000	0.04445	0.04748
894,360	0.01000	0.02697	0.03388
1,074,926	0.00500	0.01601	0.02355
1,336,657	0.00200	0.00777	0.01402
1,552,438	0.00100	0.00439	0.00921
1,783,850	0.00050	0.00243	0.00591
2,382,741	0.00010	0.00057	0.00194
Confidence Limit = 20%			
120,522	0.50000	0.54000	0.42000
245,805	0.20000	0.28500	0.16500
347,276	0.10000	0.14500	0.10900
456,730	0.05000	0.08410	0.06674
493,801	0.04000	0.07190	0.06016
574,902	0.02500	0.05144	0.04797
614,872	0.02000	0.04378	0.04292
745,139	0.01000	0.02627	0.02995
884,829	0.00500	0.01552	0.02045
1,084,220	0.00200	0.00755	0.01198
1,246,349	0.00100	0.00430	0.00781
1,418,332	0.00050	0.00241	0.00500
1,856,069	0.00010	0.00059	0.00166
Confidence Limit = 5%			
108,714	0.50000	0.53000	0.41000
221,037	0.20000	0.28200	0.15800
308,836	0.10000	0.14500	0.09500
401,476	0.05000	0.08428	0.06169
432,477	0.04000	0.07162	0.05513
499,753	0.02500	0.05072	0.04324
532,662	0.02000	0.04300	0.03842
638,948	0.01000	0.02559	0.02631
751,524	0.00500	0.01507	0.01772
910,174	0.00200	0.00736	0.01025
1,037,709	0.00100	0.00423	0.00666
1,171,779	0.00050	0.00240	0.00426
1,508,377	0.00010	0.00062	0.00143

Climate Scenario Sresa2-ncar

Discharge, cfs	Probability of Exceedance, Year 2000	Probability of Exceedance, Year 2050	Probability of Exceedance, Year 2100
Confidence Limit = 95%			
165,544	0.50000	0.60000	0.60000
362,145	0.20000	0.27000	0.40000
545,194	0.10000	0.12500	0.18900
760,721	0.05000	0.06300	0.13500
837,341	0.04000	0.04800	0.12100
1,010,641	0.02500	0.03000	0.08800
1,098,719	0.02000	0.02280	0.07220
1,396,870	0.01000	0.01070	0.04530
1,733,590	0.00500	0.00500	0.02660
2,240,895	0.00200	0.00180	0.01320
2,673,925	0.00100	0.00084	0.00716
3,151,331	0.00050	0.00043	0.00437
4,440,231	0.00010	0.00006	0.00114
Confidence Limit = 80%			
149,124	0.50000	0.58000	0.62000
315,401	0.20000	0.28000	0.40000
462,468	0.10000	0.13000	0.22000
630,079	0.05000	0.06600	0.14300
688,596	0.04000	0.05200	0.12200
819,299	0.02500	0.03200	0.09060
884,962	0.02000	0.02500	0.07560
1,104,061	0.01000	0.01215	0.04645
1,346,685	0.00500	0.00560	0.02820
1,704,783	0.00200	0.00215	0.01325
2,004,848	0.00100	0.00096	0.00798
2,330,828	0.00050	0.00047	0.00478
3,191,257	0.00010	0.00008	0.00124
Confidence Limit = 50%			
134,031	0.50000	0.60000	0.60000
276,906	0.20000	0.29000	0.38000
397,502	0.10000	0.13200	0.21800
530,974	0.05000	0.07000	0.14500
576,822	0.04000	0.06500	0.11440
678,096	0.02500	0.03400	0.09300
728,451	0.02000	0.02700	0.07840
894,360	0.01000	0.01350	0.04810
1,074,926	0.00500	0.00610	0.02950
1,336,657	0.00200	0.00240	0.01380
1,552,438	0.00100	0.00110	0.00850
1,783,850	0.00050	0.00051	0.00509
2,382,741	0.00010	0.00007	0.00143
Confidence Limit = 20%			
120,522	0.50000	0.59000	0.59000
245,805	0.20000	0.29500	0.38500
347,276	0.10000	0.13500	0.22500
456,730	0.05000	0.07200	0.14800
493,801	0.04000	0.05800	0.12620
574,902	0.02500	0.03600	0.09400
614,872	0.02000	0.02950	0.08010
745,139	0.01000	0.01440	0.04960
884,829	0.00500	0.00660	0.03040
1,084,220	0.00200	0.00260	0.01480
1,246,349	0.00100	0.00119	0.00881
1,418,332	0.00050	0.00056	0.00505
1,856,069	0.00010	0.00010	0.00151
Confidence Limit = 5%			
108,714	0.50000	0.60000	0.60000
221,037	0.20000	0.26000	0.44000
308,836	0.10000	0.14300	0.22700
401,476	0.05000	0.07500	0.14500
432,477	0.04000	0.06300	0.10100
499,753	0.02500	0.03800	0.09400
532,662	0.02000	0.03100	0.08100
638,948	0.01000	0.01550	0.05010
751,524	0.00500	0.00700	0.03100
910,174	0.00200	0.00285	0.01555
1,037,709	0.00100	0.00127	0.00933
1,171,779	0.00050	0.00060	0.00574
1,508,377	0.00010	0.00013	0.00155

Table 6-3 Inflow Ranges (Bins) For Analysis of Future Conditions

Bin #	LN (Lower Value)	LN (Upper Value)	Lower Value	Upper Value	Designated Bin Value(1)
1	12.20607	12.42066	200,000	247,871	223,936
2	12.42066	12.63526	247,871	307,201	277,536
3	12.63526	12.84985	307,201	380,731	343,966
4	12.84985	13.06444	380,731	471,861	426,296
5	13.06444	13.27903	471,861	584,804	528,332
6	13.27903	13.49362	584,804	724,780	654,792
7	13.49362	13.70821	724,780	898,260	811,520
8	13.70821	13.92281	898,260	1,113,264	1,005,762
9	13.92281	14.13740	1,113,264	1,379,730	1,246,497
10	14.13740	14.35199	1,379,730	1,709,976	1,544,853
11	14.35199	14.56658	1,709,976	2,119,269	1,914,622
12	14.56658	14.78117	2,119,269	2,626,528	2,372,898
13	14.78117	14.99577	2,626,528	3,255,202	2,940,865
14	14.99577	15.21036	3,255,202	4,034,354	3,644,778
15	15.21036	15.42495	4,034,354	5,000,000	4,517,177

Table 6-4 Annual Probability of Exceedance

Upper & Lower Limits of Inflow Bins, cfs	Probability of Exceedance, CL = 95%	Probability of Exceedance, CL = 80%	Probability of Exceedance, CL = 50%	Probability of Exceedance, CL = 20%	Probability of Exceedance, CL = 5%	Upper & Lower Limits of Inflow Bins, cfs	Probability of Exceedance, CL = 95%	Probability of Exceedance, CL = 80%	Probability of Exceedance, CL = 50%	Probability of Exceedance, CL = 20%	Probability of Exceedance, CL = 5%
Climate Scenario: Sresb1-gfdl						**Climate Scenario: Sresb1-ncar**					
Year 2100						**Year 2100**					
200,000	0.4530000	0.4190000	0.3760000	0.3070000	0.2540000	200,000	0.6280000	0.5680000	0.5480000	0.5170000	0.4750000
247,871	0.3880000	0.3400000	0.2770000	0.2170000	0.1680000	247,871	0.5820000	0.5300000	0.4970000	0.4680000	0.4190000
307,201	0.3090000	0.2560000	0.1910000	0.1550000	0.1210000	307,201	0.5280000	0.4830000	0.4470000	0.4140000	0.3550000
380,731	0.2290000	0.1780000	0.1315000	0.1110000	0.0795000	380,731	0.4700000	0.4350000	0.4000000	0.3400000	0.2200000
471,861	0.1650000	0.1205000	0.0910000	0.0745000	0.0488000	471,861	0.4260000	0.3780000	0.3150000	0.2370000	0.1950000
584,804	0.1180000	0.0935000	0.0635000	0.0410000	0.0280000	584,804	0.3680000	0.2940000	0.2180000	0.1760000	0.1470000
724,780	0.0900000	0.0620000	0.0405000	0.0240000	0.0143000	724,780	0.2830000	0.2160000	0.1670000	0.1360000	0.1070000
898,260	0.0695000	0.0390000	0.0230000	0.0128000	0.0073000	898,260	0.2190000	0.1580000	0.1230000	0.0970000	0.0680000
1,113,264	0.0381000	0.0225000	0.0137000	0.0065000	0.0028000	1,113,264	0.1630000	0.1300000	0.0950000	0.0625000	0.0420000
1,379,730	0.0247000	0.0146000	0.0063000	0.0026000	0.0014000	1,379,730	0.1220000	0.0970000	0.0627000	0.0430000	0.0270000
1,709,976	0.0160000	0.0077000	0.0032000	0.0013000	0.0007000	1,709,976	0.0987000	0.0607000	0.0425000	0.0300000	0.0125000
2,119,269	0.0092000	0.0037500	0.0015300	0.0007000	0.0002800	2,119,269	0.0675000	0.0415000	0.0285000	0.0130000	0.0042000
2,626,528	0.0050000	0.0019200	0.0006800	0.0003300	0.0000000	2,626,528	0.0503000	0.0283000	0.0165000	0.0055000	0.0003000
3,255,202	0.0027800	0.0008200	0.0003300	0.0000000	0	3,255,202	0.0340000	0.0200000	0.0085000	0.0017000	0
4,034,354	0.0013500	0.0004000	0.0000000	0	0	4,034,354	0.0243000	0.0126000	0.0039000	0	0
5,000,000	0.0005600	0.0000700	0.0000000	0	0	5,000,000	0.0141900	0.0050000	0.0004300	0	0
Year 2050						**Year 2050**					
200,000	0.4400000	0.4010000	0.3560000	0.3000000	0.2500000	200,000	0.5440000	0.5210000	0.4800000	0.4370000	0.3980000
247,871	0.3700000	0.3170000	0.2580000	0.2070000	0.1620000	247,871	0.4930000	0.4570000	0.4095000	0.3570000	0.3140000
307,201	0.2840000	0.2250000	0.1735000	0.1385000	0.1110000	307,201	0.4310000	0.3830000	0.3300000	0.2730000	0.2290000
380,731	0.2030000	0.1560000	0.1242000	0.0905000	0.0700000	380,731	0.3610000	0.3040000	0.2460000	0.1970000	0.1580000
471,861	0.1470000	0.1105000	0.0835000	0.0552000	0.0408000	471,861	0.2840000	0.2290000	0.1790000	0.1210000	0.1100000
584,804	0.1050000	0.0800000	0.0535000	0.0330000	0.0215000	584,804	0.2130000	0.1620000	0.1270000	0.0970000	0.0730000
724,780	0.0730000	0.0478000	0.0282000	0.0175000	0.0093000	724,780	0.1545000	0.1180000	0.0890000	0.0635000	0.0440000
898,260	0.0480000	0.0290000	0.0163000	0.0080000	0.0045000	898,260	0.1180000	0.0835000	0.0600000	0.0385000	0.0250000
1,113,264	0.0303000	0.0167000	0.0080000	0.0035000	0.0015000	1,113,264	0.0835000	0.0580000	0.0370000	0.0222000	0.0133000
1,379,730	0.0176000	0.0084500	0.0036000	0.0013800	0.0007000	1,379,730	0.0613000	0.0370000	0.0215000	0.0110000	0.0072000
1,709,976	0.0098000	0.0043500	0.0015000	0.0007000	0.0003000	1,709,976	0.0400000	0.0228000	0.0123000	0.0068000	0.0026000
2,119,269	0.0053000	0.0018500	0.0008000	0.0003500	0.0000000	2,119,269	0.0251000	0.0138000	0.0073000	0.0027000	0.0003700
2,626,528	0.0026500	0.0009300	0.0004000	0.0000000	0	2,626,528	0.0164000	0.0082200	0.0037000	0.0004600	0
3,255,202	0.0011900	0.0005300	0.0000700	0.0000000	0	3,255,202	0.0096500	0.0043500	0.0012000	0.0000000	0
4,034,354	0.0007000	0.0001300	0.0000000	0	0	4,034,354	0.0060000	0.0023000	0.0002800	0	0
5,000,000	0.0003500	0.0000000	0.0000000	0	0	5,000,000	0.0033000	0.0005600	0.0000000	0	0
Year 2000						**Year 2000**					
200,000	0.4950000	0.4030000	0.3530000	0.2990000	0.2470000	200,000	0.4950000	0.4030000	0.3530000	0.2990000	0.2470000
247,871	0.3650000	0.3100000	0.2510000	0.1970000	0.1550000	247,871	0.3650000	0.3100000	0.2510000	0.1970000	0.1550000
307,201	0.2572000	0.2100000	0.1620000	0.1270000	0.1028000	307,201	0.2572000	0.2100000	0.1620000	0.1270000	0.1028000
380,731	0.1820000	0.1390000	0.1095000	0.0805000	0.0595000	380,731	0.1820000	0.1390000	0.1095000	0.0805000	0.0595000
471,861	0.1265000	0.0955000	0.0685000	0.0445000	0.0308000	471,861	0.1265000	0.0955000	0.0685000	0.0445000	0.0308000
584,804	0.0870000	0.0610000	0.0388000	0.0235000	0.0145000	584,804	0.0870000	0.0610000	0.0388000	0.0235000	0.0145000

Table 6-4 Annual Probability of Exceedance

Upper & Lower Limits of Inflow Bins, cfs	Probability of Exceedance, CL = 95%	Probability of Exceedance, CL = 80%	Probability of Exceedance, CL = 50%	Probability of Exceedance, CL = 20%	Probability of Exceedance, CL = 5%	Upper & Lower Limits of Inflow Bins, cfs	Probability of Exceedance, CL = 95%	Probability of Exceedance, CL = 80%	Probability of Exceedance, CL = 50%	Probability of Exceedance, CL = 20%	Probability of Exceedance, CL = 5%
Climate Scenario: Sresb1-gfdl						**Climate Scenario: Sresb1-ncar**					
724,780	0.0565000	0.0355000	0.0202000	0.0112000	0.0063000	724,780	0.0565000	0.0355000	0.0202000	0.0112000	0.0063000
898,260	0.0381000	0.0193000	0.0099000	0.0047000	0.0022000	898,260	0.0381000	0.0193000	0.0099000	0.0047000	0.0022000
1,113,264	0.0196000	0.0097000	0.0044000	0.0017000	0.0006350	1,113,264	0.0196000	0.0097000	0.0044000	0.0017000	0.0006350
1,379,730	0.0104200	0.0046000	0.0017000	0.0005650	0.0002400	1,379,730	0.0104200	0.0046000	0.0017000	0.0005650	0.0002400
1,709,976	0.0052250	0.0019700	0.0005950	0.0002220	0.0000600	1,709,976	0.0052250	0.0019700	0.0005950	0.0002220	0.0000600
2,119,269	0.0025450	0.0007550	0.0002600	0.0000750	0	2,119,269	0.0025450	0.0007550	0.0002600	0.0000750	0
2,626,528	0.0010800	0.0003380	0.0000850	0.0000230	0	2,626,528	0.0010800	0.0003380	0.0000850	0.0000230	0
3,255,202	0.0004520	0.0000950	0.0000500	0	0	3,255,202	0.0004520	0.0000950	0.0000500	0	0
4,034,354	0.0002150	0.0000620	0.0000090	0	0	4,034,354	0.0002150	0.0000620	0.0000090	0	0
5,000,000	0.0000830	0.0000210	0	0	0	5,000,000	0.0000830	0.0000210	0	0	0
Climate Scenario: Sresa2-gfdl						**Climate Scenario: Sresa2-ncar**					
Year 2100						**Year 2100**					
200,000	0.4160000	0.3635000	0.3015000	0.2480000	0.1970000	200,000	0.5650000	0.5530000	0.4970000	0.4620000	0.4760000
247,871	0.3520000	0.2910000	0.2190000	0.1625000	0.1300000	247,871	0.5170000	0.4880000	0.4230000	0.3830000	0.3770000
307,201	0.2765000	0.2130000	0.1540000	0.1250000	0.0960000	307,201	0.4570000	0.4100000	0.3350000	0.2810000	0.2300000
380,731	0.2055000	0.1595000	0.1200000	0.0950000	0.0680000	380,731	0.3780000	0.3130000	0.2350000	0.1950000	0.1610000
471,861	0.1565000	0.1290000	0.0899000	0.0635000	0.0480000	471,861	0.2600000	0.2130000	0.1720000	0.1380000	0.0950000
584,804	0.1190000	0.0909000	0.0635000	0.0465000	0.0320000	584,804	0.1690000	0.1595000	0.1120000	0.0900000	0.0650000
724,780	0.0940000	0.0643000	0.0478000	0.0317000	0.0197000	724,780	0.1405000	0.1135000	0.0790000	0.0540000	0.0350000
898,260	0.0683000	0.0508000	0.0335000	0.0197000	0.0107000	898,260	0.1175000	0.0740000	0.0470000	0.0290000	0.0165000
1,113,264	0.0540000	0.0373000	0.0219000	0.0110000	0.0050500	1,113,264	0.0708000	0.0455000	0.0267000	0.0132000	0.0070000
1,379,730	0.0420000	0.0258000	0.0127000	0.0054000	0.0024500	1,379,730	0.0466000	0.0264000	0.0122000	0.0056000	0.0030000
1,709,976	0.0310000	0.0163000	0.0066500	0.0021000	0.0007030	1,709,976	0.0276000	0.0131000	0.0050900	0.0027000	0.0010000
2,119,269	0.0212000	0.0090300	0.0036500	0.0008300	0.0001730	2,119,269	0.0158000	0.0065000	0.0029500	0.0009500	0.0004000
2,626,528	0.0132000	0.0052000	0.0012100	0.0002230	0.0000140	2,626,528	0.0076100	0.0034500	0.0010000	0.0005200	0.0000000
3,255,202	0.0076500	0.0024700	0.0002920	0.0000163	0	3,255,202	0.0040700	0.0011700	0.0005900	0.0001300	0
4,034,354	0.0043000	0.0006850	0.0000300	0	0	4,034,354	0.0020000	0.0006700	0.0002000	0	0
5,000,000	0.0016600	0.0002200	0.0000080	0	0	5,000,000	0.0008200	0.0002900	0.0000000	0	0
Year 2050						**Year 2050**					
200,000	0.4930000	0.4595000	0.4150000	0.3730000	0.3245000	200,000	0.5410000	0.4850000	0.4520000	0.3970000	0.3120000
247,871	0.4263000	0.3830000	0.3410000	0.2815000	0.2325000	247,871	0.4550000	0.3930000	0.3470000	0.2900000	0.2090000
307,201	0.3440000	0.2950000	0.2370000	0.1895000	0.1460000	307,201	0.3500000	0.2910000	0.2390000	0.1850000	0.1450000
380,731	0.2610000	0.2095000	0.1605000	0.1205000	0.0950000	380,731	0.2480000	0.1980000	0.1470000	0.1080000	0.0880000
471,861	0.1825000	0.1365000	0.1075000	0.0782000	0.0595000	471,861	0.1670000	0.1240000	0.0900000	0.0645000	0.0480000
584,804	0.1240000	0.0953000	0.0698000	0.0488000	0.0337000	584,804	0.1075000	0.0795000	0.0630000	0.0340000	0.0225000
724,780	0.0843000	0.0655000	0.0450000	0.0285000	0.0172000	724,780	0.0722000	0.0460000	0.0273000	0.0165000	0.0085000
898,260	0.0632000	0.0437000	0.0267000	0.0147000	0.0078000	898,260	0.0410000	0.0240000	0.0132000	0.0061000	0.0030000
1,113,264	0.0445000	0.0270000	0.0145000	0.0067500	0.0029000	1,113,264	0.0221000	0.0117000	0.0053000	0.0022000	0.0009000
1,379,730	0.0291000	0.0157000	0.0068000	0.0027000	0.0012200	1,379,730	0.0112000	0.0051000	0.0020000	0.0006300	0.0003500
1,709,976	0.0177000	0.0080000	0.0028200	0.0011000	0.0004100	1,709,976	0.0052500	0.0021200	0.0009000	0.0002800	0.0000400
2,119,269	0.0102000	0.0035000	0.0013200	0.0004800	0.0000510	2,119,269	0.0023800	0.0009000	0.0002500	0.0000300	0.0000150
2,626,528	0.0050000	0.0017000	0.0005600	0.0000710	0	2,626,528	0.0009500	0.0003500	0.0000300	0.0000100	0

Table 6-4 Annual Probability of Exceedance

Upper & Lower Limits of Inflow Bins, cfs	Probability of Exceedance, CL = 95%	Probability of Exceedance, CL = 80%	Probability of Exceedance, CL = 50%	Probability of Exceedance, CL = 20%	Probability of Exceedance, CL = 5%	Upper & Lower Limits of Inflow Bins, cfs	Probability of Exceedance, CL = 95%	Probability of Exceedance, CL = 80%	Probability of Exceedance, CL = 50%	Probability of Exceedance, CL = 20%	Probability of Exceedance, CL = 5%
Climate Scenario: Sresb1-gfdl						**Climate Scenario: Sresb1-ncar**					
3,255,202	0.0022900	0.0007700	0.0000800	0.0000100	0	3,255,202	0.0005000	0.0000600	0.0000000	0.0000000	0
4,034,354	0.0011400	0.0002650	0.0000230	0	0	4,034,354	0.0001100	0.0000280	0.0000000	0	0
5,000,000	0.0004680	0.0000500	0.0000014	0	0	5,000,000	0.0000280	0.0000100	0.0000000	0	0
Year 2000						**Year 2000**					
200,000	0.4950000	0.4030000	0.3530000	0.2990000	0.2470000	200,000	0.4950000	0.4030000	0.3530000	0.2990000	0.2470000
247,871	0.3650000	0.3100000	0.2510000	0.1970000	0.1550000	247,871	0.3650000	0.3100000	0.2510000	0.1970000	0.1550000
307,201	0.2572000	0.2100000	0.1620000	0.1270000	0.1028000	307,201	0.2572000	0.2100000	0.1620000	0.1270000	0.1028000
380,731	0.1820000	0.1390000	0.1095000	0.0805000	0.0595000	380,731	0.1820000	0.1390000	0.1095000	0.0805000	0.0595000
471,861	0.1265000	0.0955000	0.0685000	0.0445000	0.0308000	471,861	0.1265000	0.0955000	0.0685000	0.0445000	0.0308000
584,804	0.0870000	0.0610000	0.0388000	0.0235000	0.0145000	584,804	0.0870000	0.0610000	0.0388000	0.0235000	0.0145000
724,780	0.0565000	0.0355000	0.0202000	0.0112000	0.0063000	724,780	0.0565000	0.0355000	0.0202000	0.0112000	0.0063000
898,260	0.0381000	0.0193000	0.0099000	0.0047000	0.0022000	898,260	0.0381000	0.0193000	0.0099000	0.0047000	0.0022000
1,113,264	0.0196000	0.0097000	0.0044000	0.0017000	0.0006350	1,113,264	0.0196000	0.0097000	0.0044000	0.0017000	0.0006350
1,379,730	0.0104200	0.0046000	0.0017000	0.0005650	0.0002400	1,379,730	0.0104200	0.0046000	0.0017000	0.0005650	0.0002400
1,709,976	0.0052250	0.0019700	0.0005950	0.0002220	0.0000600	1,709,976	0.0052250	0.0019700	0.0005950	0.0002220	0.0000600
2,119,269	0.0025450	0.0007550	0.0002600	0.0000750	0	2,119,269	0.0025450	0.0007550	0.0002600	0.0000750	0
2,626,528	0.0010800	0.0003380	0.0000850	0.0000230	0	2,626,528	0.0010800	0.0003380	0.0000850	0.0000230	0
3,255,202	0.0004520	0.0000950	0.0000500	0	0	3,255,202	0.0004520	0.0000950	0.0000500	0	0
4,034,354	0.0002150	0.0000620	0.0000090	0	0	4,034,354	0.0002150	0.0000620	0.0000090	0	0
5,000,000	0.0000830	0.0000210	0	0	0	5,000,000	0.0000830	0.0000210	0	0	0

Table 6-5 Annual Probability of Occurrence

Bin Number	Mean Bin Inflow	Probability of Occurrence, CL = 95%	Probability of Occurrence, CL = 80%	Probability of Occurrence, CL = 50%	Probability of Occurrence, CL = 20%	Probability of Occurrence, CL = 5%	Bin Number	Mean Bin Inflow	Probability of Occurrence, CL = 95%	Probability of Occurrence, CL = 80%	Probability of Occurrence, CL = 50%	Probability of Occurrence, CL = 20%	Probability of Occurrence, CL = 5%
Climate Scenario: Sresb1-gfdl							**Climate Scenario: Sresb1-ncar**						
Year 2100							**Year 2100**						
1	223,936	0.0650000	0.0790000	0.0990000	0.0900000	0.0860000	1	223,936	0.0460000	0.0380000	0.0510000	0.0490000	0.0560000
2	277,536	0.0790000	0.0840000	0.0860000	0.0620000	0.0470000	2	277,536	0.0540000	0.0470000	0.0500000	0.0540000	0.0640000
3	343,966	0.0800000	0.0780000	0.0595000	0.0440000	0.0415000	3	343,966	0.0580000	0.0480000	0.0470000	0.0740000	0.1350000
4	426,296	0.0640000	0.0575000	0.0405000	0.0365000	0.0307000	4	426,296	0.0440000	0.0570000	0.0850000	0.1030000	0.0250000
5	528,332	0.0470000	0.0270000	0.0275000	0.0335000	0.0208000	5	528,332	0.0580000	0.0840000	0.0970000	0.0610000	0.0480000
6	654,792	0.0280000	0.0315000	0.0230000	0.0170000	0.0137000	6	654,792	0.0850000	0.0780000	0.0510000	0.0400000	0.0400000
7	811,520	0.0205000	0.0230000	0.0175000	0.0112000	0.0070000	7	811,520	0.0640000	0.0580000	0.0440000	0.0390000	0.0390000
8	1,005,762	0.0314000	0.0165000	0.0093000	0.0063000	0.0045000	8	1,005,762	0.0560000	0.0280000	0.0280000	0.0345000	0.0260000
9	1,246,497	0.0134000	0.0079000	0.0074000	0.0039000	0.0014000	9	1,246,497	0.0410000	0.0330000	0.0323000	0.0195000	0.0150000
10	1,544,853	0.0087000	0.0069000	0.0031000	0.0013000	0.0007000	10	1,544,853	0.0233000	0.0363000	0.0202000	0.0130000	0.0145000
11	1,914,622	0.0068000	0.0039500	0.0016700	0.0006000	0.0004200	11	1,914,622	0.0312000	0.0192000	0.0140000	0.0170000	0.0083000
12	2,372,898	0.0042000	0.0018300	0.0008500	0.0003700	0.0002800	12	2,372,898	0.0172000	0.0132000	0.0120000	0.0075000	0.0039000
13	2,940,865	0.0022200	0.0011000	0.0003500	0.0003300	0.0000000	13	2,940,865	0.0163000	0.0083000	0.0080000	0.0038000	0.0003000
14	3,644,778	0.0014300	0.0004200	0.0003300	0.0000000	0.0000000	14	3,644,778	0.0097000	0.0074000	0.0046000	0.0017000	0.0000000
15	4,517,177	0.0007900	0.0003300	0.0000000	0.0000000	0.0000000	15	4,517,177	0.0101100	0.0076000	0.0034700	0.0000000	0.0000000
Year 2050							**Year 2050**						
1	223,936	0.0700000	0.0840000	0.0980000	0.0930000	0.0880000	1	223,936	0.0510000	0.0640000	0.0705000	0.0800000	0.0840000
2	277,536	0.0860000	0.0920000	0.0845000	0.0685000	0.0510000	2	277,536	0.0620000	0.0740000	0.0795000	0.0840000	0.0850000
3	343,966	0.0810000	0.0690000	0.0493000	0.0480000	0.0410000	3	343,966	0.0700000	0.0790000	0.0840000	0.0760000	0.0710000
4	426,296	0.0560000	0.0455000	0.0407000	0.0353000	0.0292000	4	426,296	0.0770000	0.0750000	0.0670000	0.0760000	0.0480000
5	528,332	0.0420000	0.0305000	0.0300000	0.0222000	0.0193000	5	528,332	0.0710000	0.0670000	0.0520000	0.0240000	0.0370000
6	654,792	0.0320000	0.0322000	0.0253000	0.0155000	0.0122000	6	654,792	0.0585000	0.0440000	0.0380000	0.0335000	0.0290000
7	811,520	0.0250000	0.0188000	0.0119000	0.0095000	0.0048000	7	811,520	0.0365000	0.0345000	0.0290000	0.0250000	0.0190000
8	1,005,762	0.0177000	0.0123000	0.0083000	0.0045000	0.0030000	8	1,005,762	0.0345000	0.0255000	0.0230000	0.0163000	0.0117000
9	1,246,497	0.0127000	0.0082500	0.0044000	0.0021200	0.0008000	9	1,246,497	0.0222000	0.0210000	0.0155000	0.0112000	0.0061000
10	1,544,853	0.0078000	0.0041000	0.0021000	0.0006800	0.0004000	10	1,544,853	0.0213000	0.0142000	0.0092000	0.0042000	0.0046000
11	1,914,622	0.0045000	0.0025000	0.0007000	0.0003500	0.0003000	11	1,914,622	0.0149000	0.0090000	0.0050000	0.0041000	0.0022300
12	2,372,898	0.0026500	0.0009200	0.0004000	0.0003500	0.0000000	12	2,372,898	0.0087000	0.0055800	0.0036000	0.0022400	0.0003700
13	2,940,865	0.0014600	0.0004000	0.0003300	0.0000000	0.0000000	13	2,940,865	0.0067500	0.0038700	0.0025000	0.0004600	0.0000000
14	3,644,778	0.0004900	0.0004000	0.0000700	0.0000000	0.0000000	14	3,644,778	0.0036500	0.0020500	0.0009200	0.0000000	0.0000000
15	4,517,177	0.0003500	0.0001300	0.0000000	0.0000000	0.0000000	15	4,517,177	0.0027000	0.0017400	0.0002800	0.0000000	0.0000000
Year 2000							**Year 2000**						
1	223,936	0.1300000	0.0930000	0.1020000	0.1020000	0.0920000	1	223,936	0.1300000	0.0930000	0.1020000	0.1020000	0.0920000
2	277,536	0.1078000	0.1000000	0.0890000	0.0700000	0.0522000	2	277,536	0.1078000	0.1000000	0.0890000	0.0700000	0.0522000
3	343,966	0.0752000	0.0710000	0.0525000	0.0465000	0.0433000	3	343,966	0.0752000	0.0710000	0.0525000	0.0465000	0.0433000
4	426,296	0.0555000	0.0435000	0.0410000	0.0360000	0.0287000	4	426,296	0.0555000	0.0435000	0.0410000	0.0360000	0.0287000
5	528,332	0.0395000	0.0345000	0.0297000	0.0210000	0.0163000	5	528,332	0.0395000	0.0345000	0.0297000	0.0210000	0.0163000
6	654,792	0.0305000	0.0255000	0.0186000	0.0123000	0.0082000	6	654,792	0.0305000	0.0255000	0.0186000	0.0123000	0.0082000
7	811,520	0.0184000	0.0162000	0.0103000	0.0065000	0.0041000	7	811,520	0.0184000	0.0162000	0.0103000	0.0065000	0.0041000
8	1,005,762	0.0185000	0.0096000	0.0055000	0.0030000	0.0015650	8	1,005,762	0.0185000	0.0096000	0.0055000	0.0030000	0.0015650
9	1,246,497	0.0091800	0.0051000	0.0027000	0.0011350	0.0003950	9	1,246,497	0.0091800	0.0051000	0.0027000	0.0011350	0.0003950

Table 6-5 Annual Probability of Occurrence

Bin Number	Mean Bin Inflow	Probability of Occurrence, CL = 95%	Probability of Occurrence, CL = 80%	Probability of Occurrence, CL = 50%	Probability of Occurrence, CL = 20%	Probability of Occurrence, CL = 5%	Bin Number	Mean Bin Inflow	Probability of Occurrence, CL = 95%	Probability of Occurrence, CL = 80%	Probability of Occurrence, CL = 50%	Probability of Occurrence, CL = 20%	Probability of Occurrence, CL = 5%
Climate Scenario: Sresb1-gfdl							**Climate Scenario: Sresb1-ncar**						
10	1,544,853	0.0051950	0.0026300	0.0011050	0.0003430	0.0001800	10	1,544,853	0.0051950	0.0026300	0.0011050	0.0003430	0.0001800
11	1,914,622	0.0026800	0.0012150	0.0003350	0.0001470	0.0000600	11	1,914,622	0.0026800	0.0012150	0.0003350	0.0001470	0.0000600
12	2,372,898	0.0014650	0.0004170	0.0001750	0.0000520	0.0000000	12	2,372,898	0.0014650	0.0004170	0.0001750	0.0000520	0.0000000
13	2,940,865	0.0006280	0.0002430	0.0000350	0.0000230	0.0000000	13	2,940,865	0.0006280	0.0002430	0.0000350	0.0000230	0.0000000
14	3,644,778	0.0002370	0.0000330	0.0000410	0.0000000	0.0000000	14	3,644,778	0.0002370	0.0000330	0.0000410	0.0000000	0.0000000
15	4,517,177	0.0001320	0.0000410	0.0000090	0.0000000	0.0000000	15	4,517,177	0.0001320	0.0000410	0.0000090	0.0000000	0.0000000
Climate Scenario: Sresa2-gfdl							**Climate Scenario: Sresa2-ncar**						
Year 2100							**Year 2100**						
1	223,936	0.0640000	0.0725000	0.0825000	0.0855000	0.0670000	1	223,936	0.0480000	0.0650000	0.0740000	0.0790000	0.0990000
2	277,536	0.0755000	0.0780000	0.0650000	0.0375000	0.0340000	2	277,536	0.0600000	0.0780000	0.0880000	0.1020000	0.1470000
3	343,966	0.0710000	0.0535000	0.0340000	0.0300000	0.0280000	3	343,966	0.0790000	0.0970000	0.1000000	0.0860000	0.0690000
4	426,296	0.0490000	0.0305000	0.0301000	0.0315000	0.0200000	4	426,296	0.1180000	0.1000000	0.0630000	0.0570000	0.0660000
5	528,332	0.0375000	0.0381000	0.0264000	0.0170000	0.0160000	5	528,332	0.0910000	0.0535000	0.0600000	0.0480000	0.0300000
6	654,792	0.0250000	0.0266000	0.0157000	0.0148000	0.0123000	6	654,792	0.0285000	0.0460000	0.0330000	0.0360000	0.0300000
7	811,520	0.0257000	0.0135000	0.0143000	0.0120000	0.0090000	7	811,520	0.0230000	0.0395000	0.0320000	0.0250000	0.0185000
8	1,005,762	0.0143000	0.0135000	0.0116000	0.0087000	0.0056500	8	1,005,762	0.0467000	0.0285000	0.0203000	0.0158000	0.0095000
9	1,246,497	0.0120000	0.0115000	0.0092000	0.0056000	0.0026000	9	1,246,497	0.0242000	0.0191000	0.0145000	0.0076000	0.0040000
10	1,544,853	0.0110000	0.0095000	0.0060500	0.0033000	0.0017470	10	1,544,853	0.0190000	0.0133000	0.0071100	0.0029000	0.0020000
11	1,914,622	0.0098000	0.0072700	0.0030000	0.0012700	0.0005300	11	1,914,622	0.0118000	0.0066000	0.0021400	0.0017500	0.0006000
12	2,372,898	0.0080000	0.0038300	0.0024400	0.0006070	0.0001590	12	2,372,898	0.0081900	0.0030500	0.0019500	0.0004300	0.0004000
13	2,940,865	0.0055500	0.0027300	0.0009180	0.0002067	0.0000140	13	2,940,865	0.0035400	0.0022800	0.0004100	0.0003900	0.0000000
14	3,644,778	0.0033500	0.0017850	0.0002620	0.0000163	0.0000000	14	3,644,778	0.0020700	0.0005000	0.0003900	0.0001300	0.0000000
15	4,517,177	0.0026400	0.0004650	0.0000221	0.0000000	0.0000000	15	4,517,177	0.0011800	0.0003800	0.0002000	0.0000000	0.0000000
Year 2050							**Year 2050**						
1	223,936	0.0667000	0.0765000	0.0740000	0.0915000	0.0920000	1	223,936	0.0860000	0.0920000	0.1050000	0.1070000	0.1030000
2	277,536	0.0823000	0.0880000	0.1040000	0.0920000	0.0865000	2	277,536	0.1050000	0.1020000	0.1080000	0.1050000	0.0640000
3	343,966	0.0830000	0.0855000	0.0765000	0.0690000	0.0510000	3	343,966	0.1020000	0.0930000	0.0920000	0.0770000	0.0570000
4	426,296	0.0785000	0.0730000	0.0530000	0.0423000	0.0355000	4	426,296	0.0810000	0.0740000	0.0570000	0.0435000	0.0400000
5	528,332	0.0585000	0.0412000	0.0377000	0.0294000	0.0258000	5	528,332	0.0595000	0.0445000	0.0270000	0.0305000	0.0255000
6	654,792	0.0397000	0.0298000	0.0248000	0.0203000	0.0165000	6	654,792	0.0353000	0.0335000	0.0357000	0.0175000	0.0140000
7	811,520	0.0211000	0.0218000	0.0183000	0.0138000	0.0094000	7	811,520	0.0312000	0.0220000	0.0141000	0.0104000	0.0055000
8	1,005,762	0.0187000	0.0167000	0.0122000	0.0079500	0.0049000	8	1,005,762	0.0189000	0.0123000	0.0079000	0.0039000	0.0021000
9	1,246,497	0.0154000	0.0113000	0.0077000	0.0040500	0.0016800	9	1,246,497	0.0109000	0.0066000	0.0033000	0.0015700	0.0005500
10	1,544,853	0.0114000	0.0077000	0.0039800	0.0016000	0.0008100	10	1,544,853	0.0059500	0.0029800	0.0011000	0.0003500	0.0003100
11	1,914,622	0.0075000	0.0045000	0.0015000	0.0006200	0.0003590	11	1,914,622	0.0028700	0.0012200	0.0006500	0.0002500	0.0000250
12	2,372,898	0.0052000	0.0018000	0.0007600	0.0004090	0.0000510	12	2,372,898	0.0014300	0.0005500	0.0002200	0.0000200	0.0000150
13	2,940,865	0.0027100	0.0009300	0.0004800	0.0000610	0.0000000	13	2,940,865	0.0004500	0.0002900	0.0000300	0.0000100	0.0000000
14	3,644,778	0.0011500	0.0005050	0.0000570	0.0000100	0.0000000	14	3,644,778	0.0003900	0.0000320	0.0000000	0.0000000	0.0000000
15	4,517,177	0.0006720	0.0002150	0.0000216	0.0000000	0.0000000	15	4,517,177	0.0000820	0.0000180	0.0000000	0.0000000	0.0000000
Year 2000							**Year 2000**						
1	223,936	0.1300000	0.0930000	0.1020000	0.1020000	0.0920000	1	223,936	0.1300000	0.0930000	0.1020000	0.1020000	0.0920000
2	277,536	0.1078000	0.1000000	0.0890000	0.0700000	0.0522000	2	277,536	0.1078000	0.1000000	0.0890000	0.0700000	0.0522000
3	343,966	0.0752000	0.0710000	0.0525000	0.0465000	0.0433000	3	343,966	0.0752000	0.0710000	0.0525000	0.0465000	0.0433000

Table 6-5 Annual Probability of Occurrence

Bin Number	Mean Bin Inflow	Probability of Occurrence, CL = 95%	Probability of Occurrence, CL = 80%	Probability of Occurrence, CL = 50%	Probability of Occurrence, CL = 20%	Probability of Occurrence, CL = 5%	Bin Number	Mean Bin Inflow	Probability of Occurrence, CL = 95%	Probability of Occurrence, CL = 80%	Probability of Occurrence, CL = 50%	Probability of Occurrence, CL = 20%	Probability of Occurrence, CL = 5%
Climate Scenario: Sresb1-gfdl							Climate Scenario: Sresb1-ncar						
4	426,296	0.0555000	0.0435000	0.0410000	0.0360000	0.0287000	4	426,296	0.0555000	0.0435000	0.0410000	0.0360000	0.0287000
5	528,332	0.0395000	0.0345000	0.0297000	0.0210000	0.0163000	5	528,332	0.0395000	0.0345000	0.0297000	0.0210000	0.0163000
6	654,792	0.0305000	0.0255000	0.0186000	0.0123000	0.0082000	6	654,792	0.0305000	0.0255000	0.0186000	0.0123000	0.0082000
7	811,520	0.0184000	0.0162000	0.0103000	0.0065000	0.0041000	7	811,520	0.0184000	0.0162000	0.0103000	0.0065000	0.0041000
8	1,005,762	0.0185000	0.0096000	0.0055000	0.0030000	0.0015650	8	1,005,762	0.0185000	0.0096000	0.0055000	0.0030000	0.0015650
9	1,246,497	0.0091800	0.0051000	0.0027000	0.0011350	0.0003950	9	1,246,497	0.0091800	0.0051000	0.0027000	0.0011350	0.0003950
10	1,544,853	0.0051950	0.0026300	0.0011050	0.0003430	0.0001800	10	1,544,853	0.0051950	0.0026300	0.0011050	0.0003430	0.0001800
11	1,914,622	0.0026800	0.0012150	0.0003350	0.0001470	0.0000600	11	1,914,622	0.0026800	0.0012150	0.0003350	0.0001470	0.0000600
12	2,372,898	0.0014650	0.0004170	0.0001750	0.0000520	0.0000000	12	2,372,898	0.0014650	0.0004170	0.0001750	0.0000520	0.0000000
13	2,940,865	0.0006280	0.0002430	0.0000350	0.0000230	0.0000000	13	2,940,865	0.0006280	0.0002430	0.0000350	0.0000230	0.0000000
14	3,644,778	0.0002370	0.0000330	0.0000410	0.0000000	0.0000000	14	3,644,778	0.0002370	0.0000330	0.0000410	0.0000000	0.0000000
15	4,517,177	0.0001320	0.0000410	0.0000090	0.0000000	0.0000000	15	4,517,177	0.0001320	0.0000410	0.0000090	0.0000000	0.0000000

Table 6-6 Probability of Occurrence of a Hydrologic Event in Future Years

Year & Confidence Limit	Probability of Hydrologic Event Being in Bin(I) Where Value & Range of Bin(I) is Given In Table 6-3							
	P = EXP[A x (QBin(I))2 + B x QBin(I) + C]			Statistical Fit, R2	P = EXP[A x (QBin(I))2 + B x QBin(I) + C]			Statistical Fit, R2
	A	B	C		A	B	C	
	Climate Change Scenario: Sresa2-gfdl				Climate Change Scenario: Sresb1-gfdl			
YEAR 2100								
95%	1.78476E-13	-1.54174E-06	-2.45948E+00	0.954	1.61899E-13	-1.81732E-06	-2.16653E+00	0.983
80%	9.40487E-14	-1.47456E-06	-2.59966E+00	0.959	2.22203E-13	-2.34454E-06	-1.99705E+00	0.991
50%	-8.61129E-14	-1.27142E-06	-2.84093E+00	0.977	4.11893E-13	-3.24743E-06	-1.74278E+00	0.995
20%	-1.11187E-13	-1.77505E-06	-2.75602E+00	0.985	7.01287E-13	-4.30825E-06	-1.53260E+00	0.994
5%	-2.29969E-13	-2.10062E-06	-2.77384E+00	0.991	9.63317E-13	-5.13977E-06	-1.46740E+00	0.995
YEAR 2050								
95%	1.26113E-13	-1.70656E-06	-2.13124E+00	0.984	1.65796E-13	-2.07067E-06	-2.04619E+00	0.995
80%	1.78997E-13	-2.23475E-06	-1.93723E+00	0.995	2.68099E-13	-2.73858E-06	-1.86383E+00	0.992
50%	1.28388E-13	-2.53767E-06	-1.90043E+00	0.992	5.99412E-13	-4.02947E-06	-1.48611E+00	0.994
20%	1.29527E-13	-3.09148E-06	-1.78396E+00	0.994	1.00562E-12	-5.30410E-06	-1.23012E+00	0.994
5%	2.42737E-13	-3.99668E-06	-1.56217E+00	0.995	1.26223E-12	-6.12977E-06	-1.16462E+00	0.992
YEAR 2000								
95%	2.32680E-13	-2.64473E-06	-1.71365E+00	0.995	2.32680E-13	-2.64473E-06	-1.71365E+00	0.995
80%	3.06446E-13	-3.32274E-06	-1.60018E+00	0.992	3.06446E-13	-3.32274E-06	-1.60018E+00	0.992
50%	4.26509E-13	-4.10926E-06	-1.47391E+00	0.994	4.26509E-13	-4.10926E-06	-1.47391E+00	0.994
20%	7.62514E-13	-5.48314E-06	-1.15630E+00	0.999	7.62514E-13	-5.48314E-06	-1.15630E+00	0.999
5%	9.92779E-13	-6.46388E-06	-1.03537E+00	0.997	9.92779E-13	-6.46388E-06	-1.03537E+00	0.997
	Climate Change Scenario: Sresa2-ncar				Climate Change Scenario: Sresb1-ncar			
YEAR 2100								
95%	4.51000E-14	-1.21140E-06	-2.28293E+00	0.936	1.65208E-14	-5.52666E-07	-2.61984E+00	0.863
80%	8.98985E-14	-1.76614E-06	-1.93062E+00	0.985	5.17210E-14	-7.97334E-07	-2.55874E+00	0.853
50%	2.37332E-13	-2.60945E-06	-1.64407E+00	0.986	5.49444E-14	-9.77816E-07	-2.44362E+00	0.938
20%	3.08201E-13	-3.16795E-06	-1.48842E+00	0.991	-2.67606E-14	-9.83750E-07	-2.42673E+00	0.952
5%	5.18293E-13	-4.09703E-06	-1.17241E+00	0.989	-5.13061E-13	-1.82185E-07	-2.77567E+00	0.929

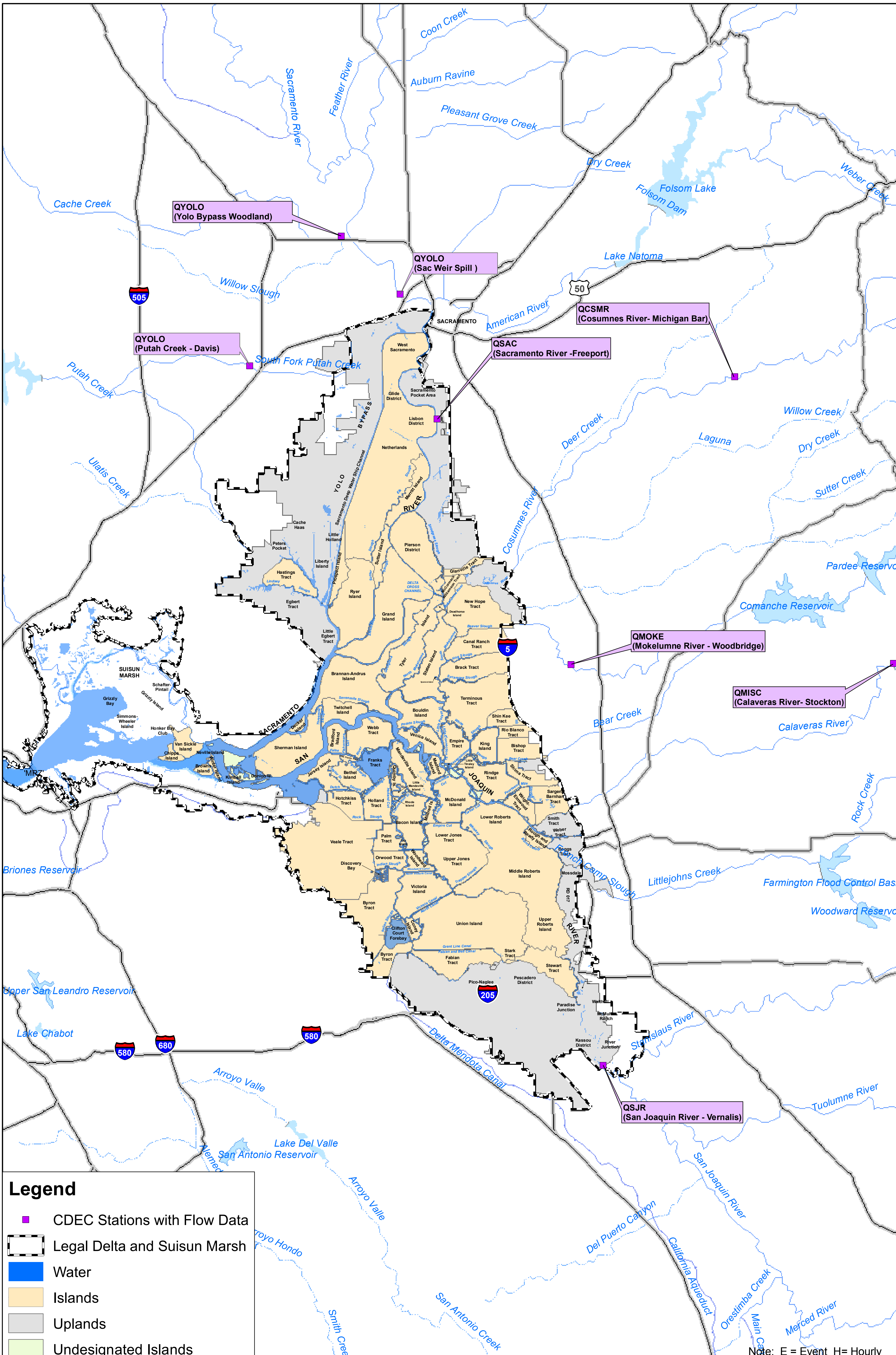
Table 6-6 Probability of Occurrence of a Hydrologic Event in Future Years

Year & Confidence Limit	Probability of Hydrologic Event Being in Bin(I) Where Value & Range of Bin(I) is Given In Table 6-3							
	P = EXP[A x (QBin(I))2 + B x QBin(I) + C]			Statistical Fit, R2	P = EXP[A x (QBin(I))2 + B x QBin(I) + C]			Statistical Fit, R2
	A	B	C		A	B	C	
YEAR 2050								
95%	1.88201E-13	-2.53249E-06	-1.61596E+00	0.993	7.45379E-14	-1.14556E-06	-2.32689E+00	0.975
80%	2.06379E-13	-3.04519E-06	-1.50099E+00	0.994	1.54421E-13	-1.65575E-06	-2.08640E+00	0.991
50%	2.28947E-13	-3.68150E-06	-1.34734E+00	0.992	8.49741E-14	-1.68202E-06	-2.13604E+00	0.991
20%	4.66652E-13	-5.02163E-06	-9.71574E+01	0.993	1.02877E-13	-2.13890E-06	-2.02355E+00	0.968
5%	6.01678E-13	-5.84877E-06	-9.13610E+01	0.991	-5.21422E-14	-2.26041E-06	-1.98892E+00	0.987
YEAR 2000								
95%	2.32680E-13	-2.64473E-06	-1.71365E+00	0.995	2.32680E-13	-2.64473E-06	-1.71365E+00	0.995
80%	3.06446E-13	-3.32274E-06	-1.60018E+00	0.992	3.06446E-13	-3.32274E-06	-1.60018E+00	0.992
50%	4.26509E-13	-4.10926E-06	-1.47391E+00	0.994	4.26509E-13	-4.10926E-06	-1.47391E+00	0.994
20%	7.62514E-13	-5.48314E-06	-1.15630E+00	0.999	7.62514E-13	-5.48314E-06	-1.15630E+00	0.999
5%	9.92779E-13	-6.46388E-06	-1.03537E+00	0.997	9.92779E-13	-6.46388E-06	-1.03537E+00	0.997

Table 6-7 Future Changes In Delta Inflow Patterns, Climate Scenario Sresa2-gfdl

Watershed Runoff Location	Average Contribution to Annual Peaks, 1951-2000	Average Contribution to Annual Peaks, 2001-2050	Average Contribution to Annual Peaks, 2051-2100
Yuba R at Smartville	11.2%	12.4%	11.6%
Sacramento R at Shasta Dam	17.6%	15.8%	17.1%
Feather R at Oroville	11.0%	12.2%	12.6%
Calaveras R at New Hogan	1.6%	1.6%	1.4%
San Joaquin R at Millerton Lake	2.2%	2.6%	2.7%
American R at Folsom Dam	8.5%	8.9%	8.1%
Cosumnes R at McConnell	3.0%	2.7%	2.3%
Bear Creek	0.9%	1.0%	0.9%
Butte Cr	0.6%	0.7%	0.6%
Tuolumne R at New Don Pedro	3.6%	4.1%	3.8%
Fresno R	0.1%	0.1%	0.1%
Kings R at Pine Flat Dam	1.7%	2.2%	2.3%
Merced R at Lake McClure	2.2%	3.0%	2.6%
March Cr	0.0%	0.0%	0.0%
Merced R at Pohono Br	0.1%	0.2%	0.2%
Stanislaus R at New Melones Dam	2.5%	2.9%	2.6%
NF American R at NF Dam	1.8%	2.1%	1.9%
Paynes Cr	0.2%	0.2%	0.2%
Mokelumne R at Pardee	2.6%	3.0%	2.5%
Sacramento R at Delta	2.6%	2.1%	2.6%
Stony Cr	0.5%	0.4%	0.4%
Thomes Cr	0.5%	0.3%	0.4%
Sacramento R at Bend Br.	24.8%	21.7%	23.2%
No. Annual Events Included In Period	**16**	**13**	**14**

Figures



0 1.5 3 6 9 12 Miles

URS | DRMS 26815431 | Flow Stations Used with Flood Hazard Analysis | Figure 2-1

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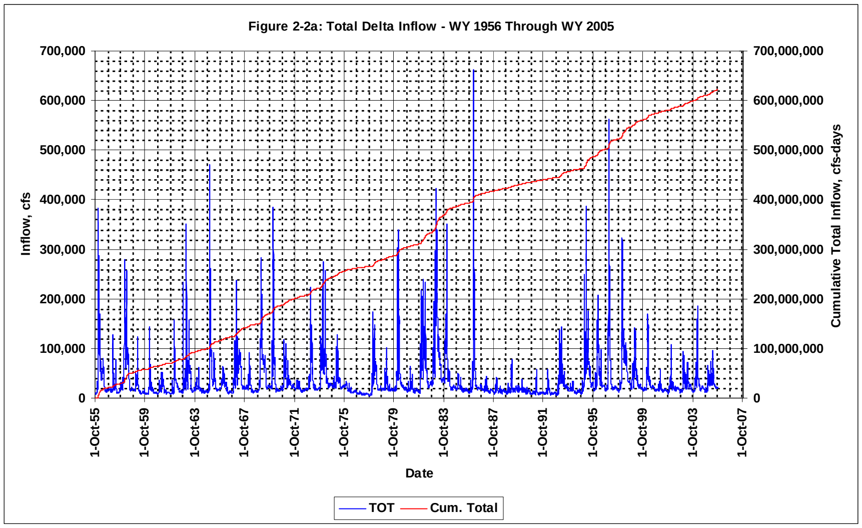
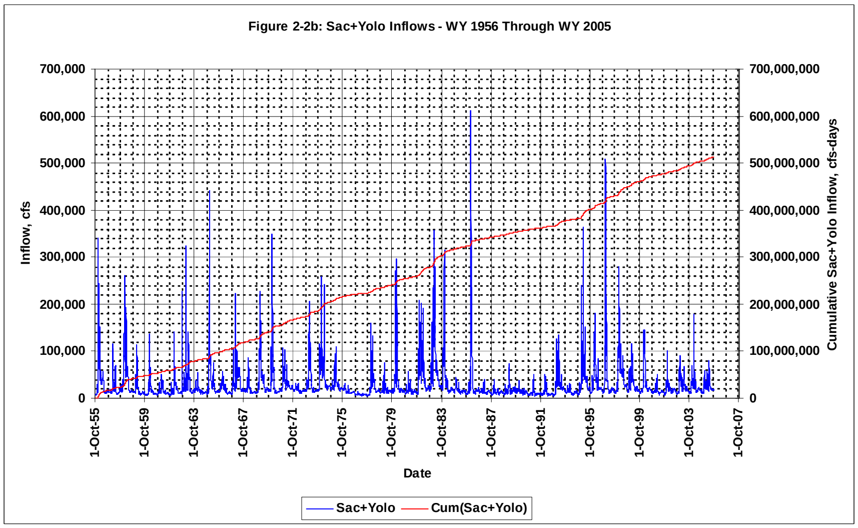
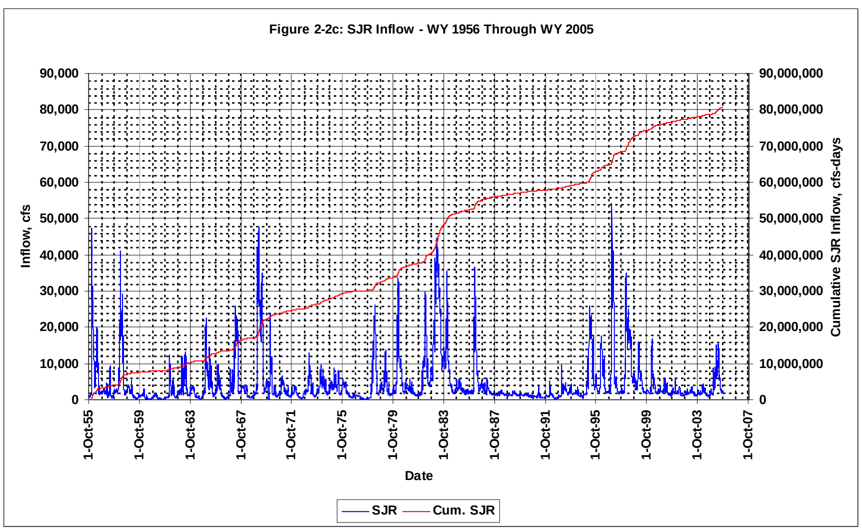
Figure 2-2 Historical Delta Inflows







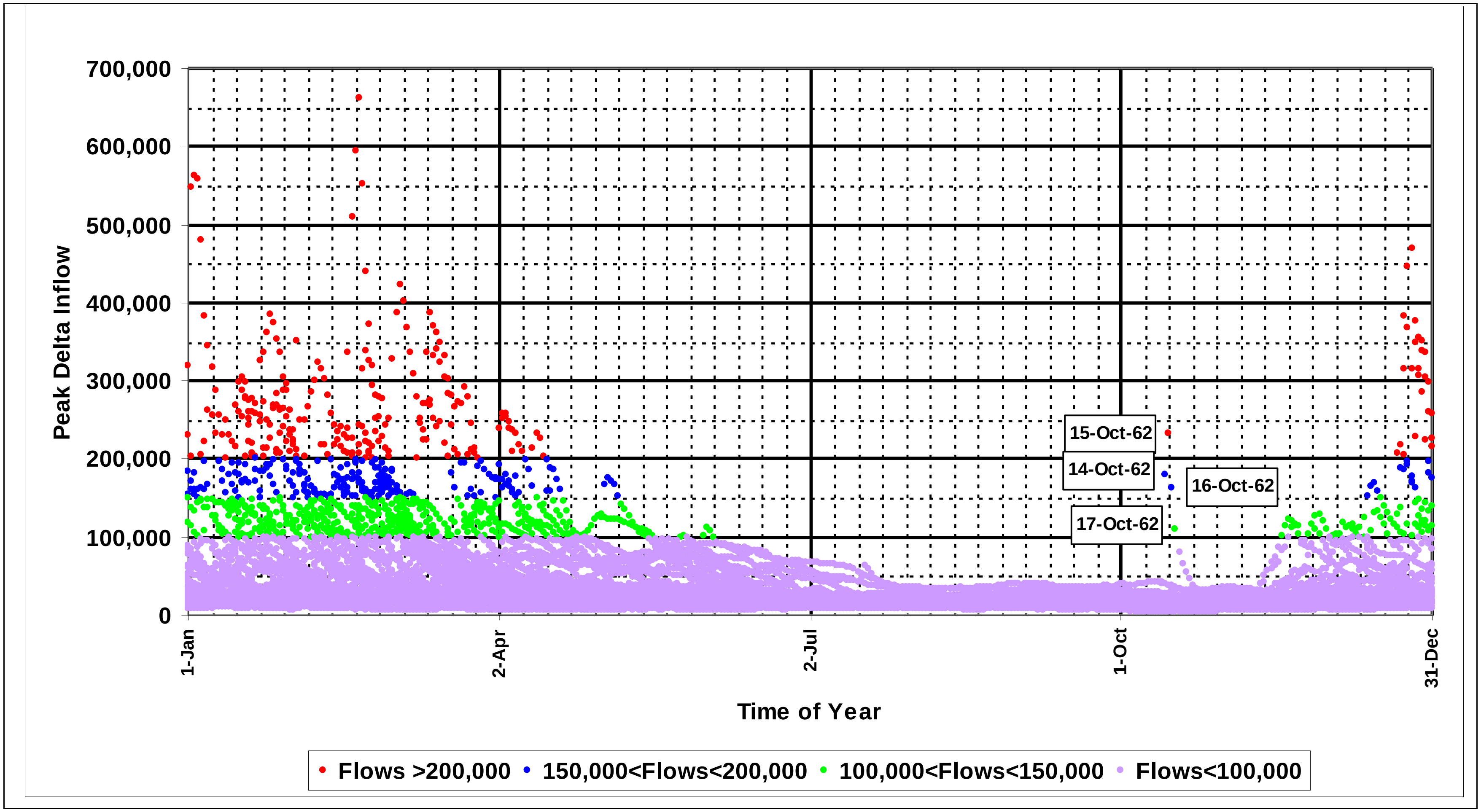


Figure 2-3 Temporal Distribution of Peak Delta Inflows

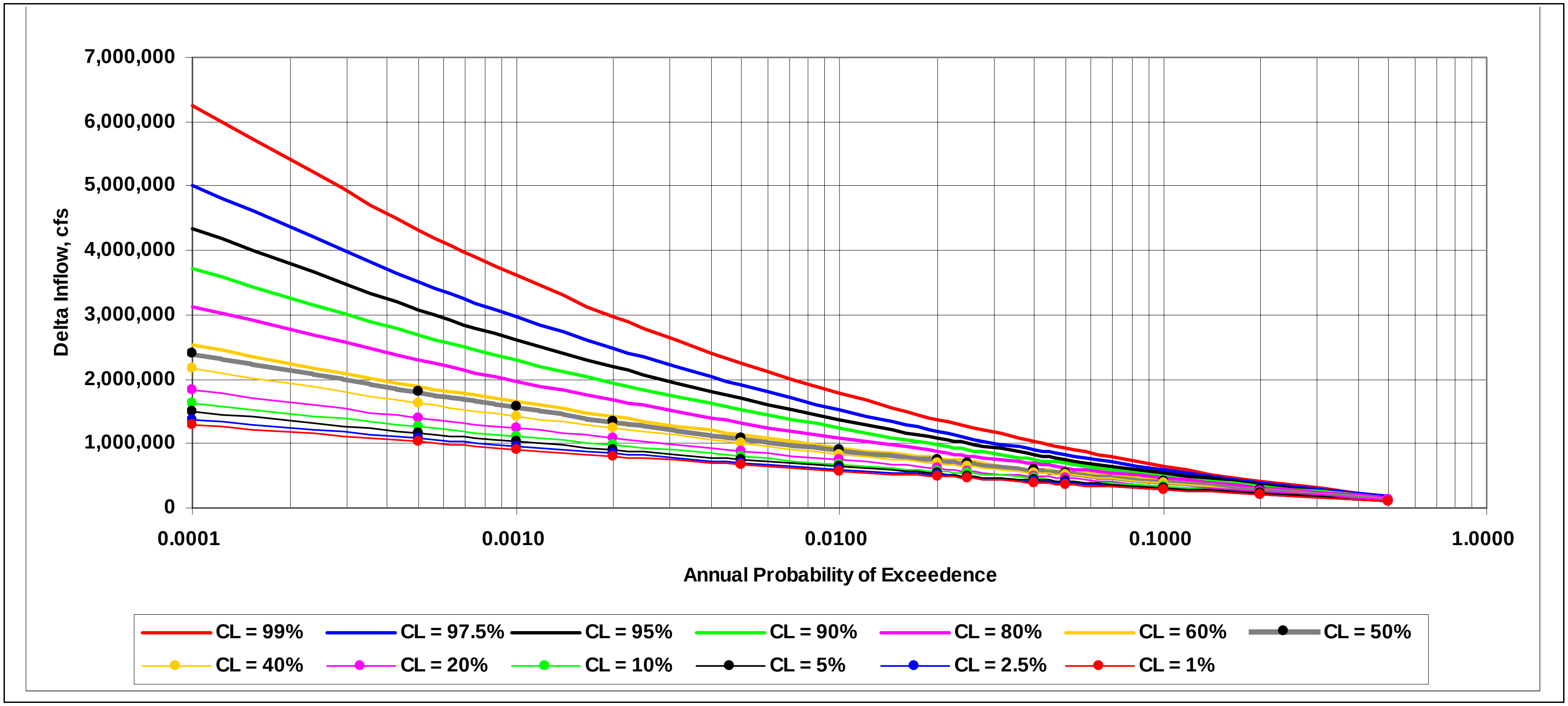


Figure 3-1 All Seasons Flow Frequency

(CL – Confidence Limit %)

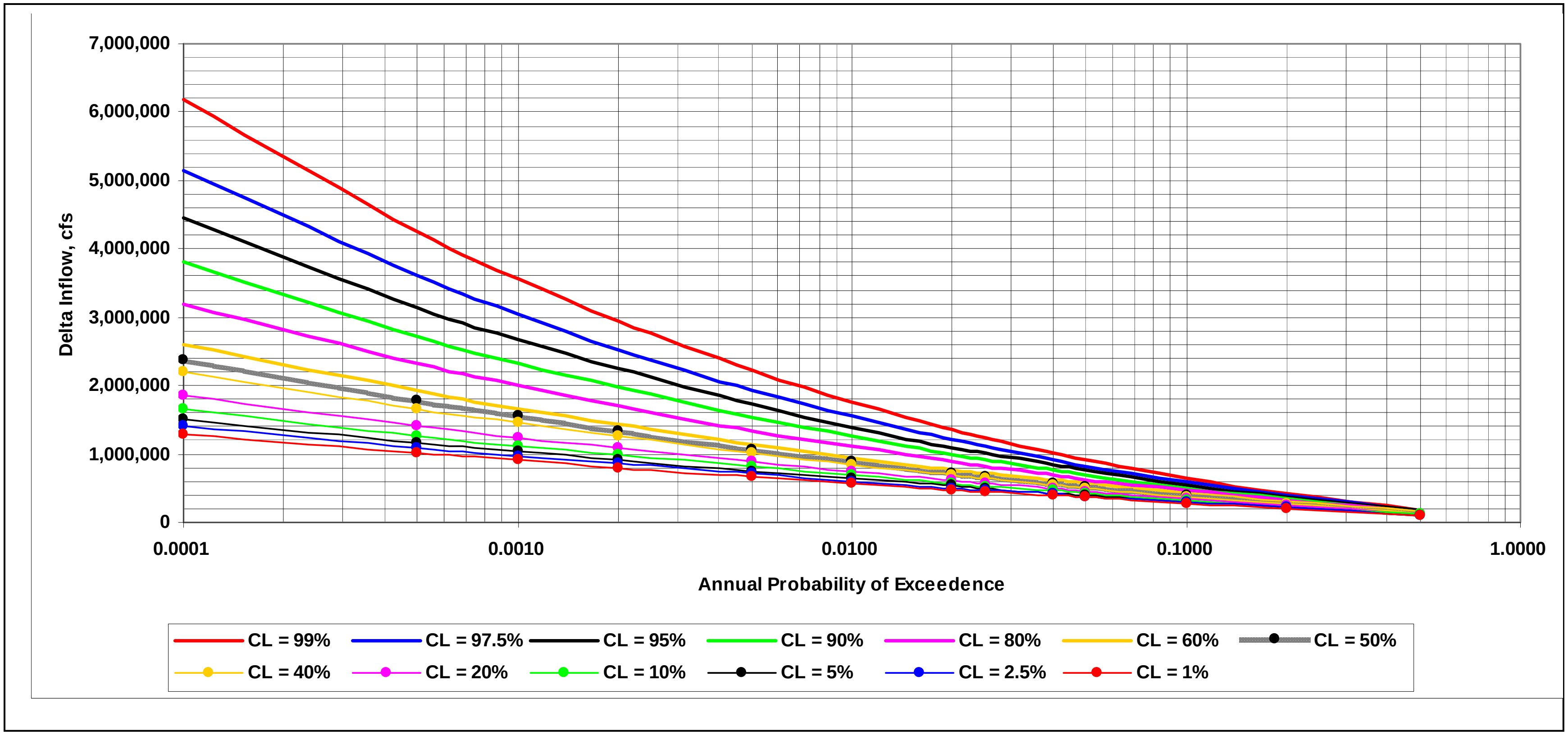


Figure 3-2 High Runoff Season – Inflow Frequency

(CL = Confidence Limit %)

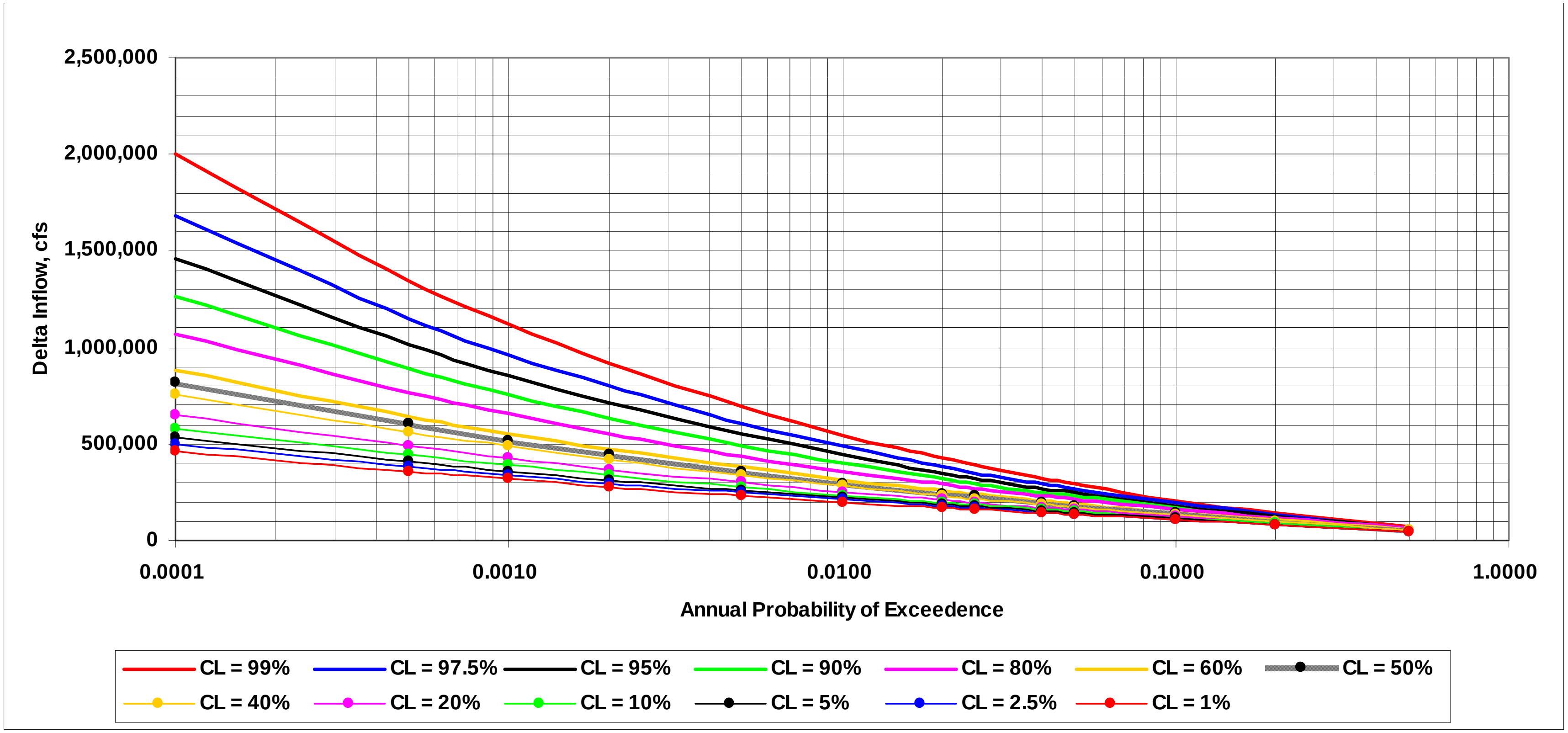


Figure 3-3 Low Runoff Season – Inflow Frequency

(CL = Confidence Limit %)

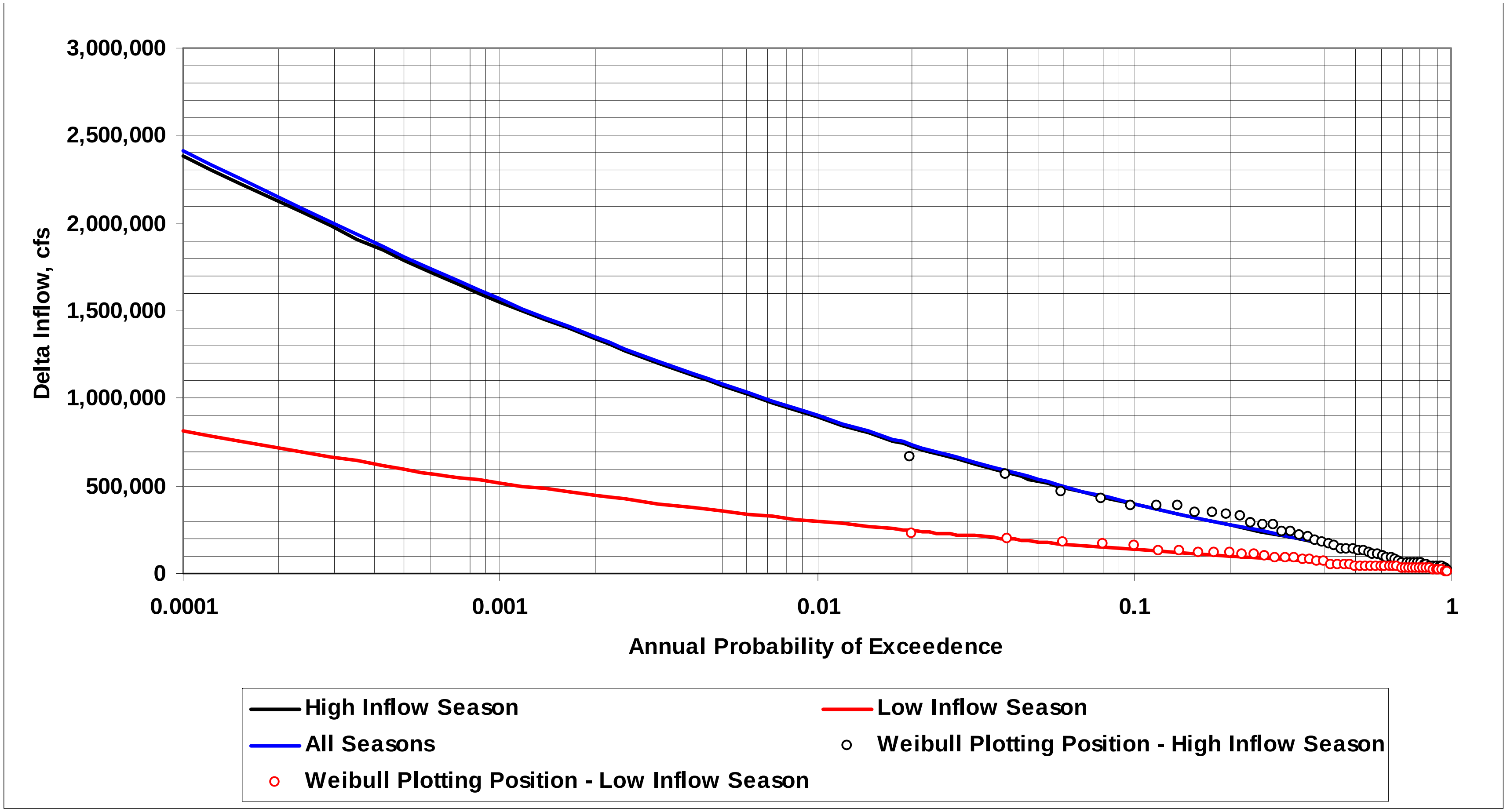


Figure 3-4 Comparison Between Inflow-Frequency Curves, CL = 50%

(CL = Confidence Limit %)

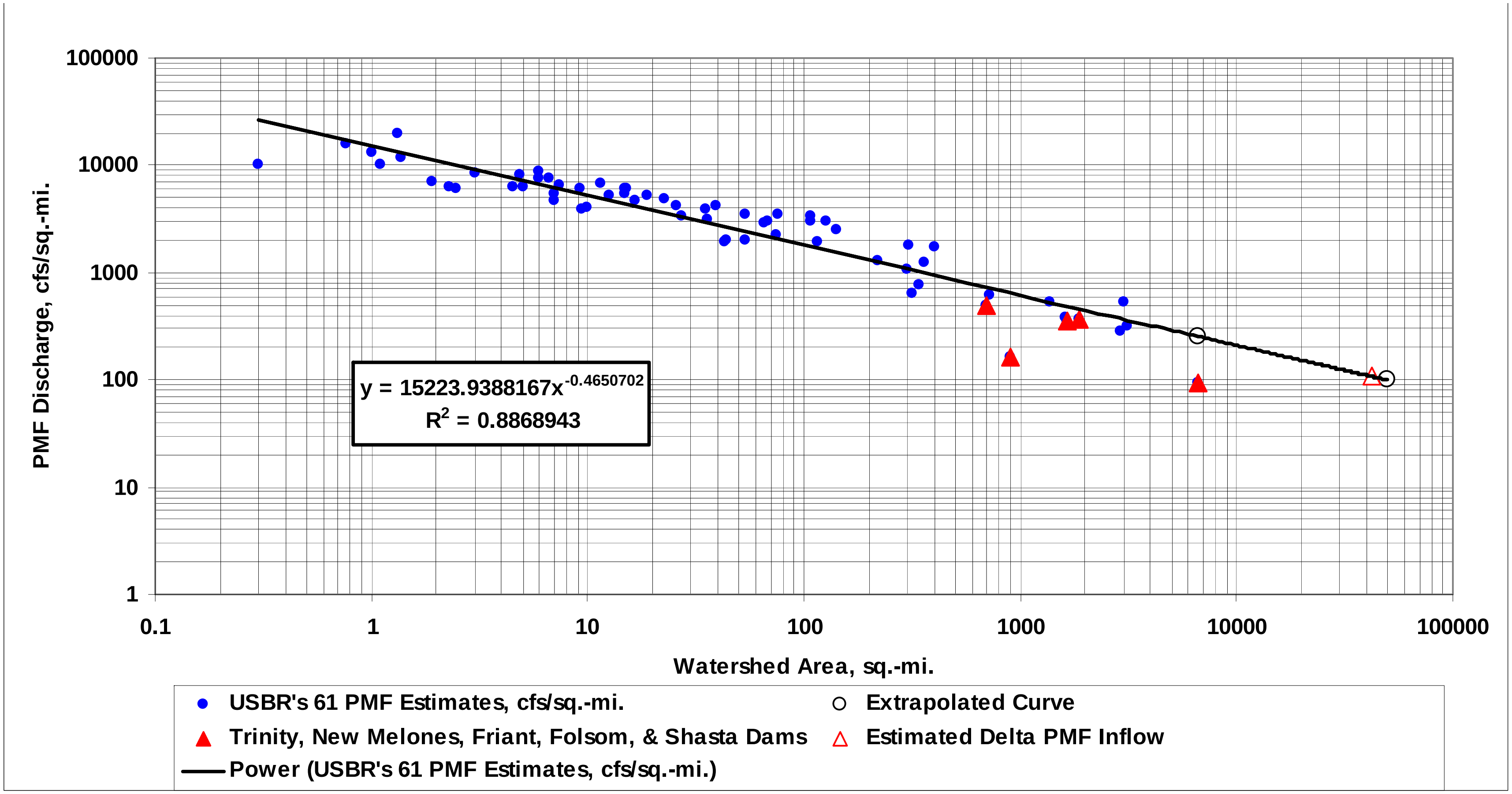


Figure 3-5 PMF Magnitudes vs. Watershed Area

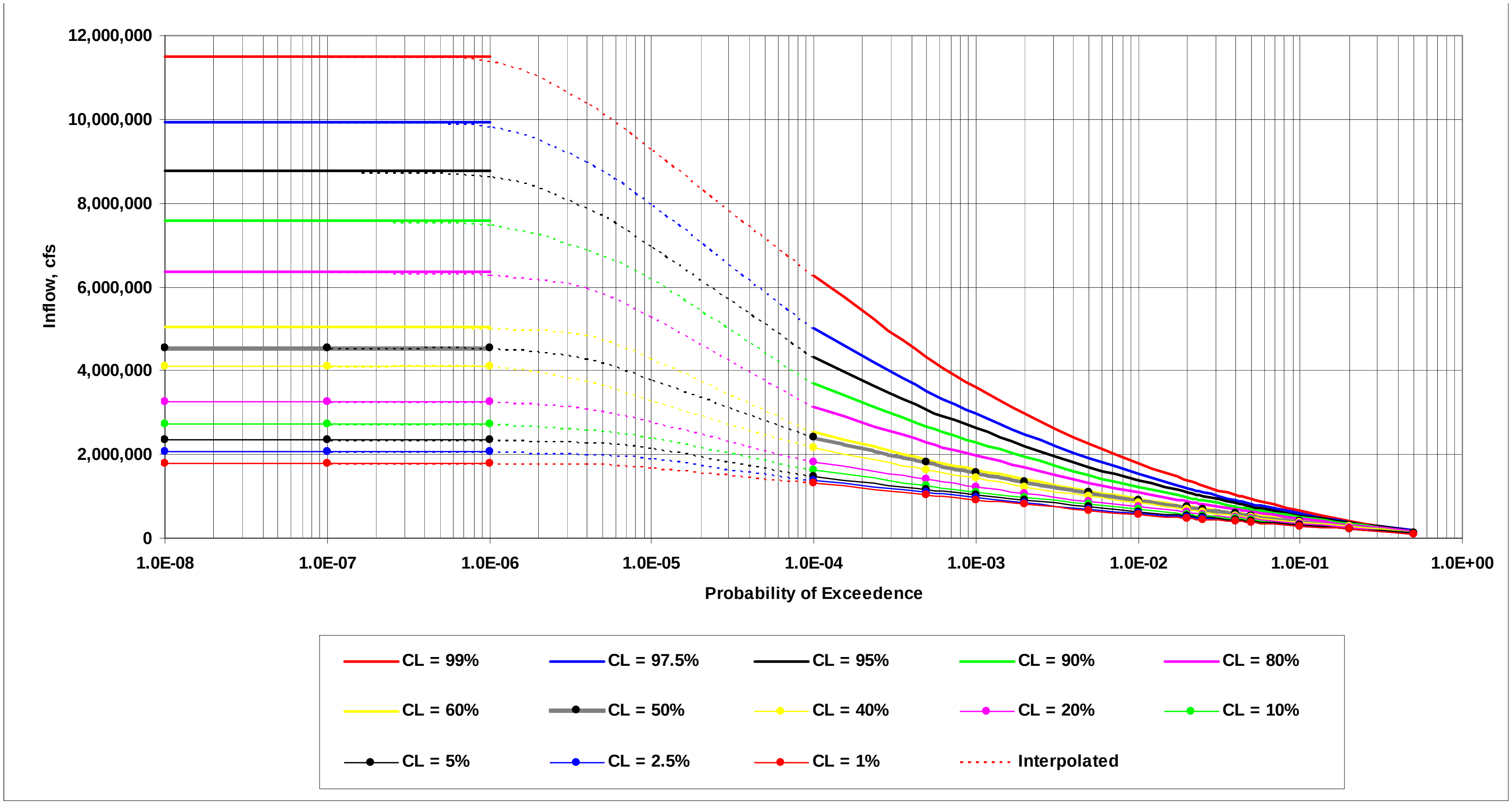


Figure 3-6 Inflow Frequency: All Seasons

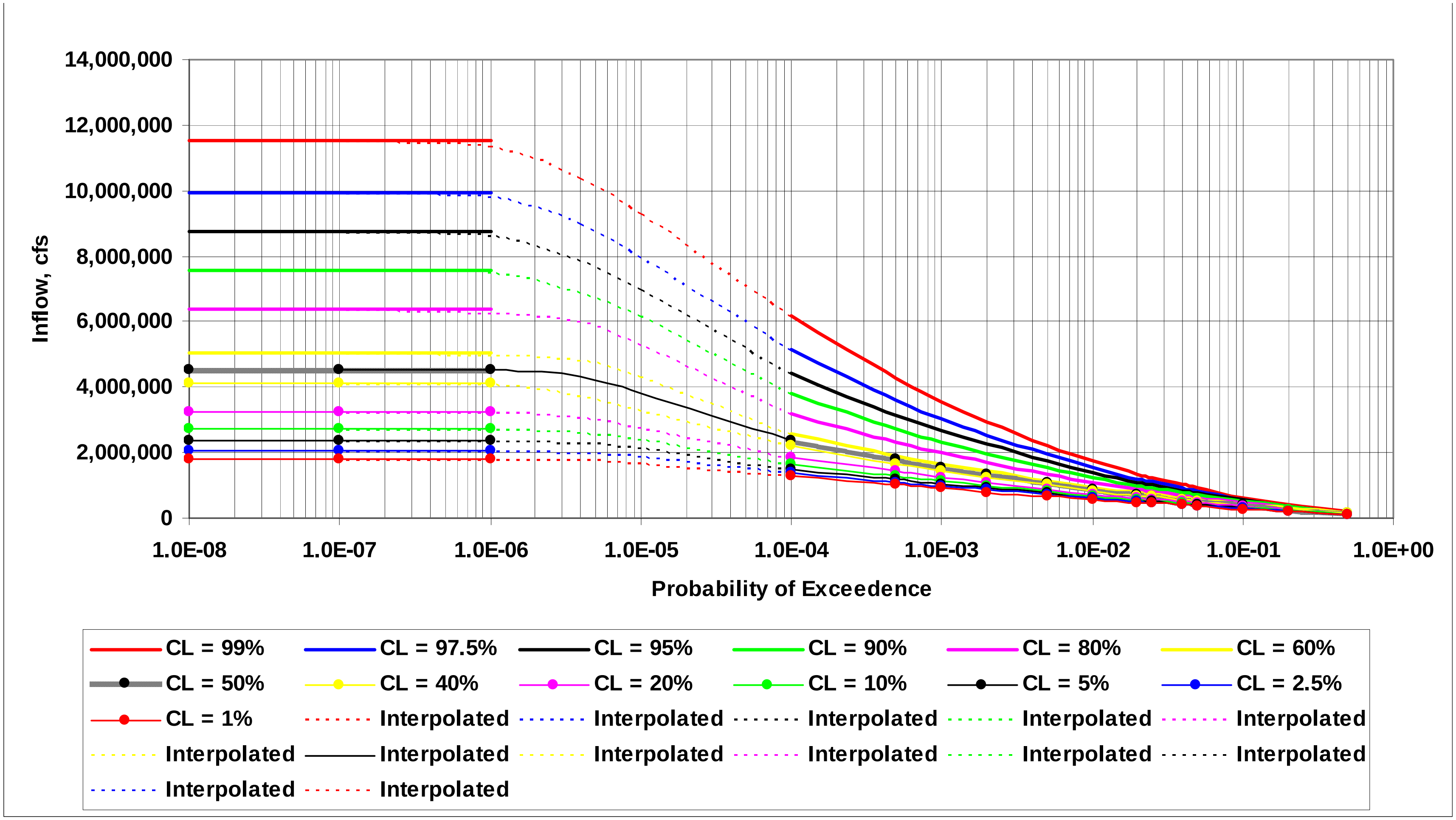


Figure 3-7 Flow Frequency: High Inflow Season, 2000

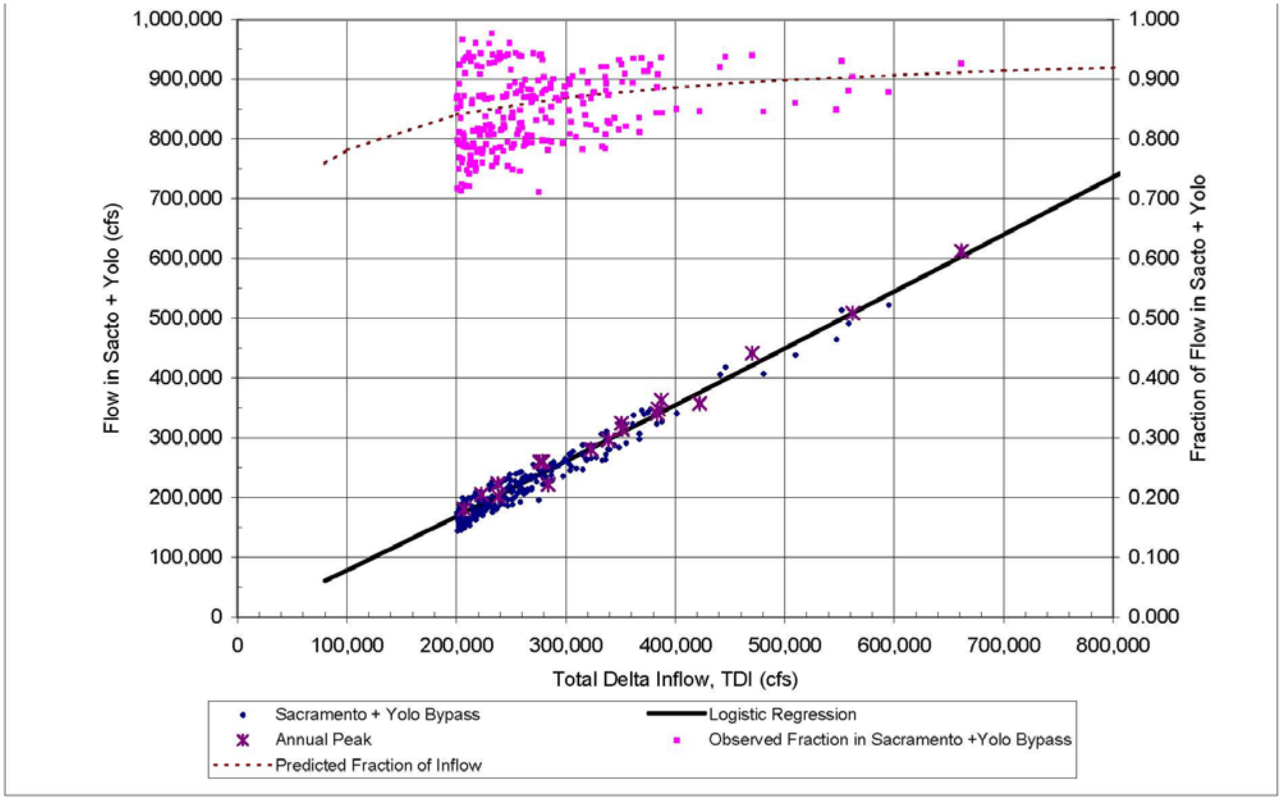


Figure 4-1 Flow in Sacramento River Plus Yolo Bypass Versus Total Delta Inflow

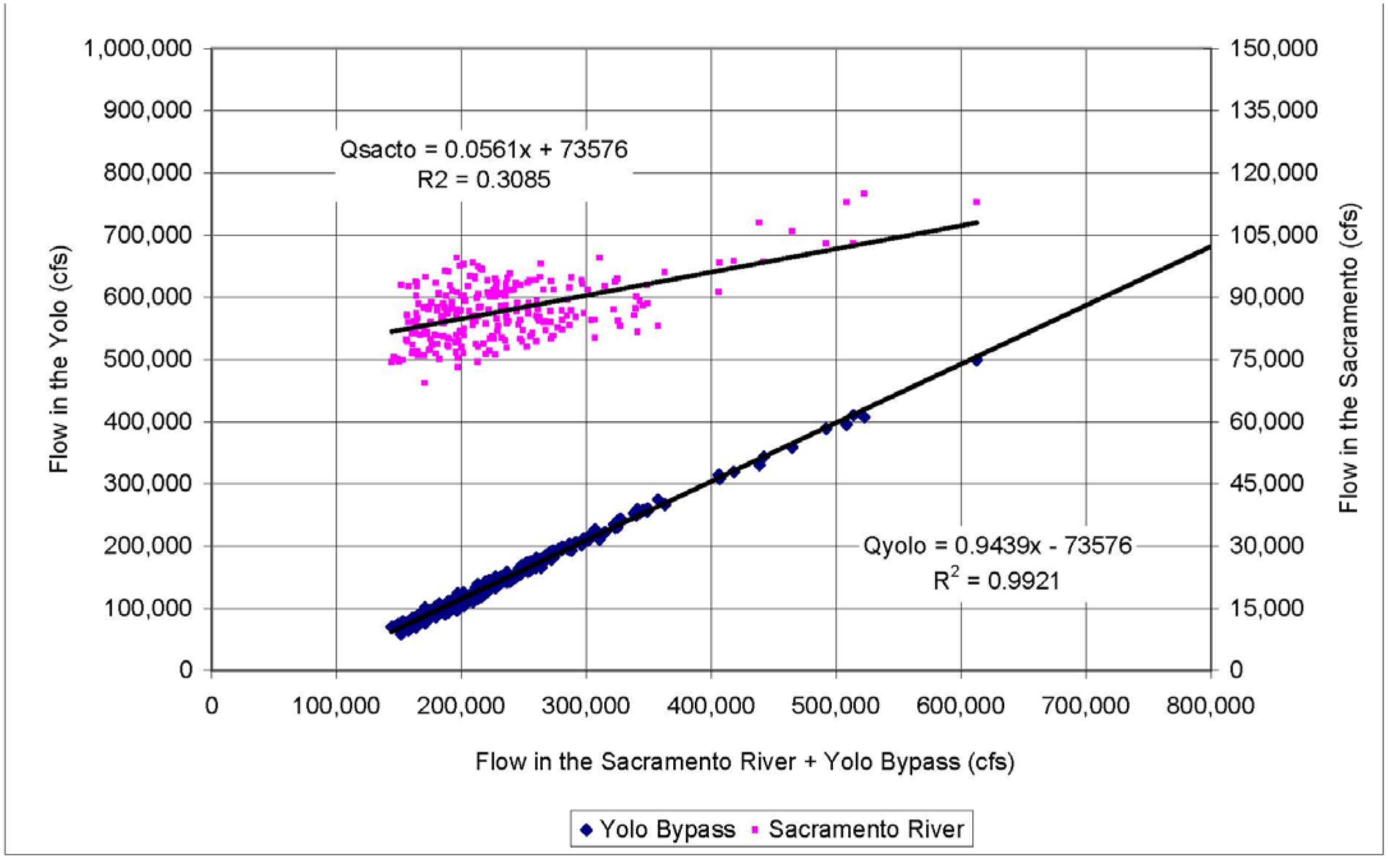


Figure 4-2 Relationship Between Flow in the Yolo Bypass and Total Flow in the Sacramento River

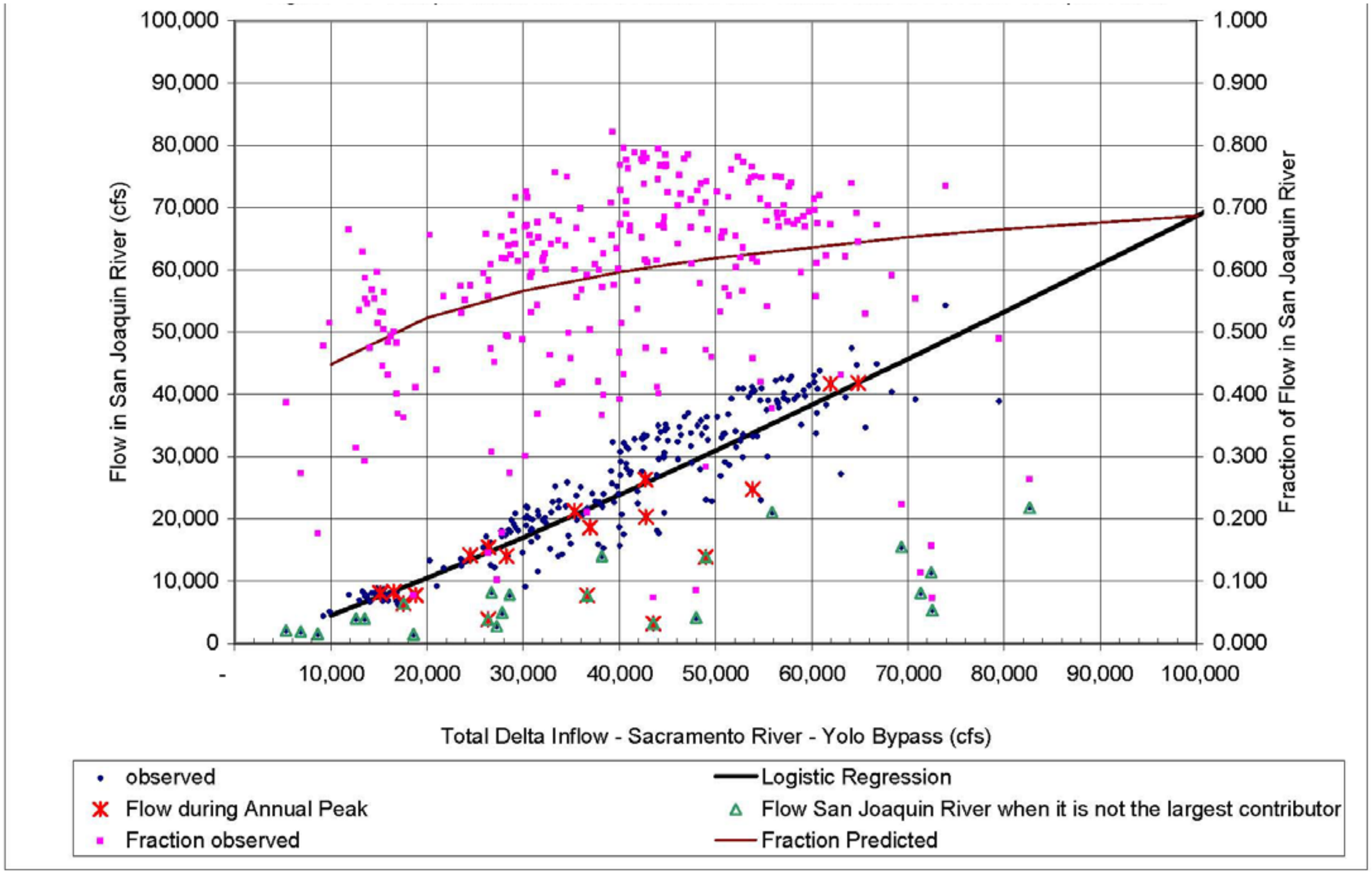


Figure 4-3 Comparison between Predicted and Observed Flow in San Joaquin River

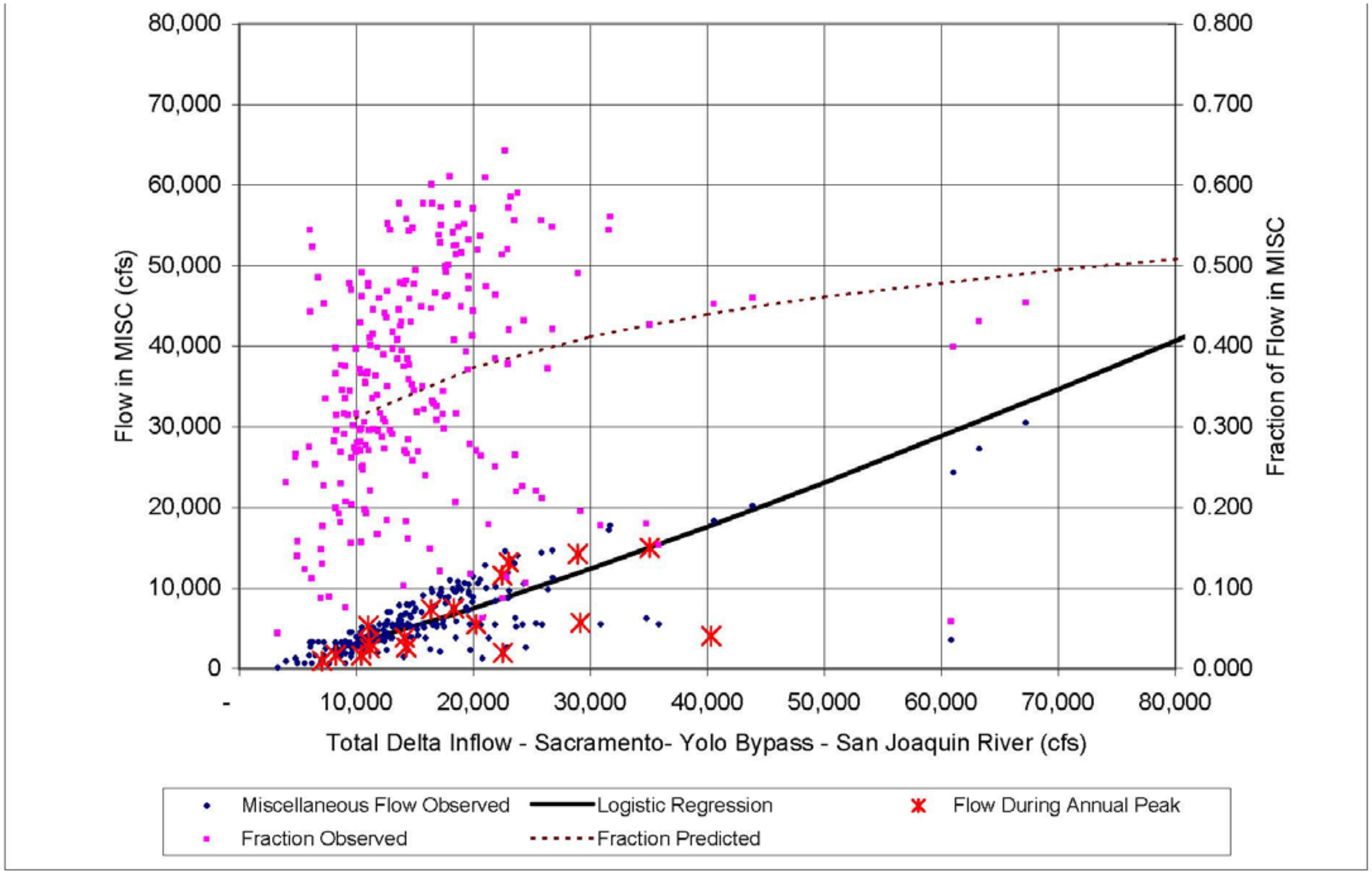


Figure 4-4 Comparison between Predicted and Observed Flows in MISC InFlow

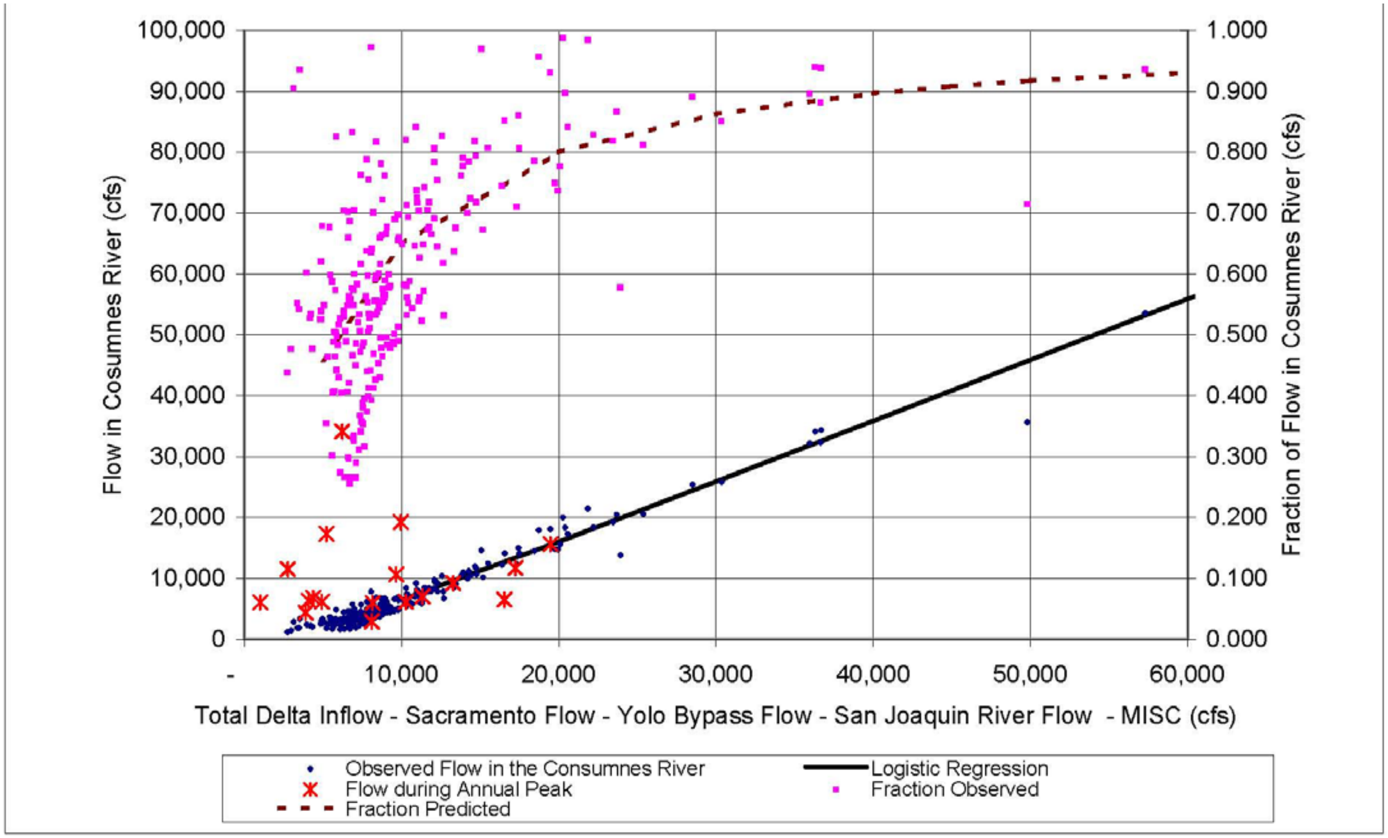


Figure 4-5 Comparison between Predicted and Observed Flows in the Cosumnes River

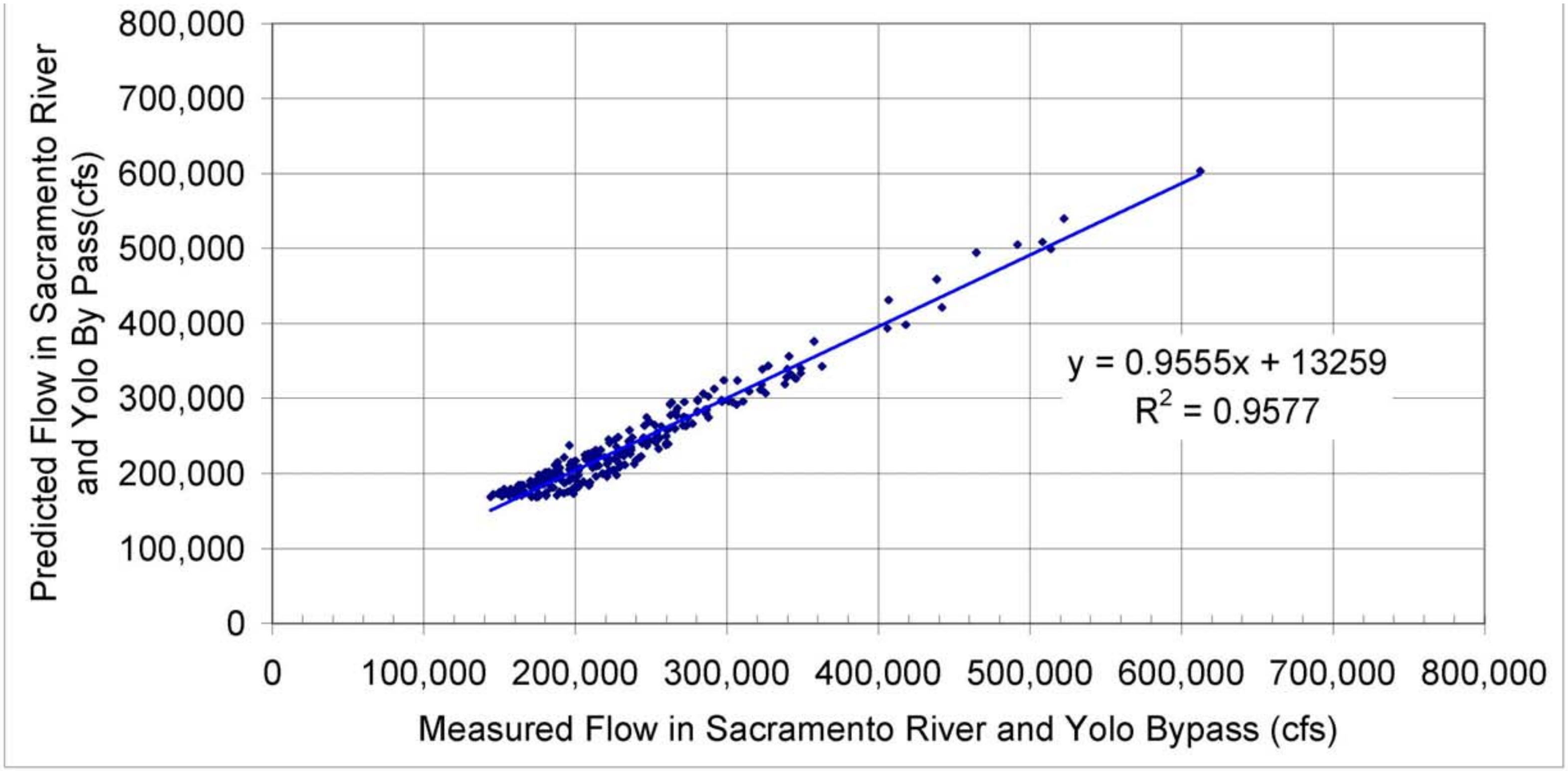


Figure 4-6 Comparison between Measured and Predicted Flows in the Sacramento and Yolo Bypass

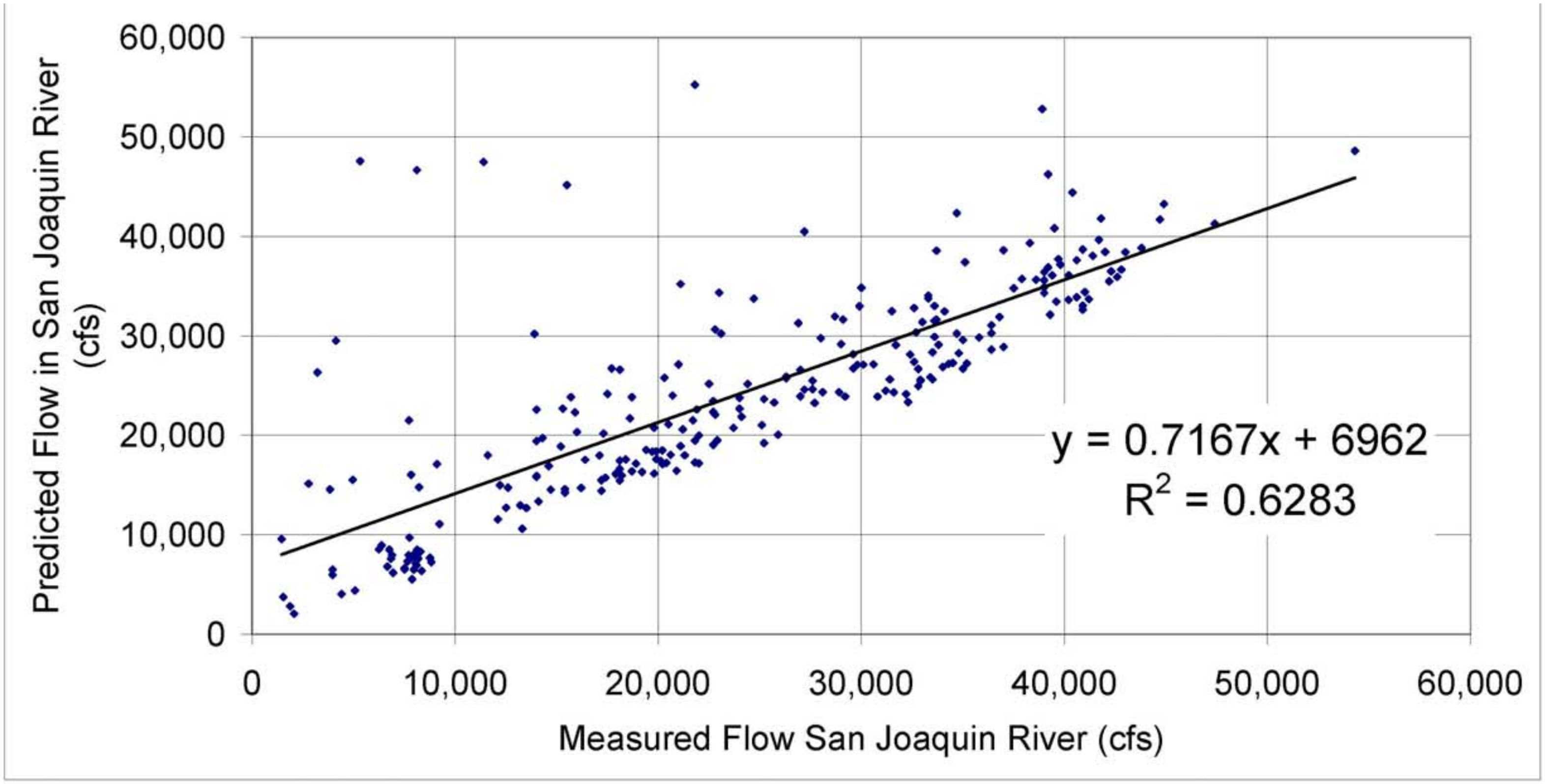


Figure 4-7 Comparison between Measured and Predicted Flows in the San Joaquin River

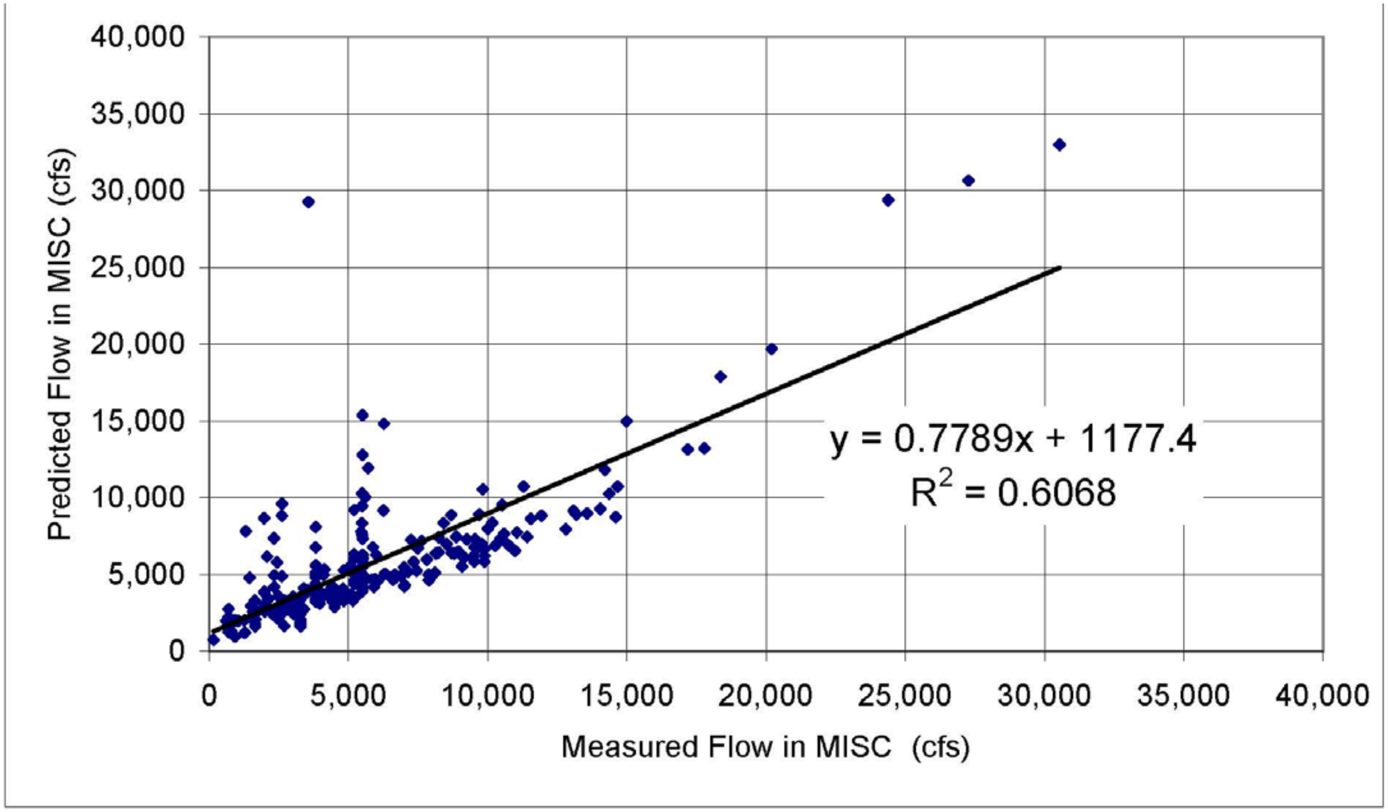


Figure 4-8 Comparison between Predicted and Measured Flows in the Miscellaneous Inflows

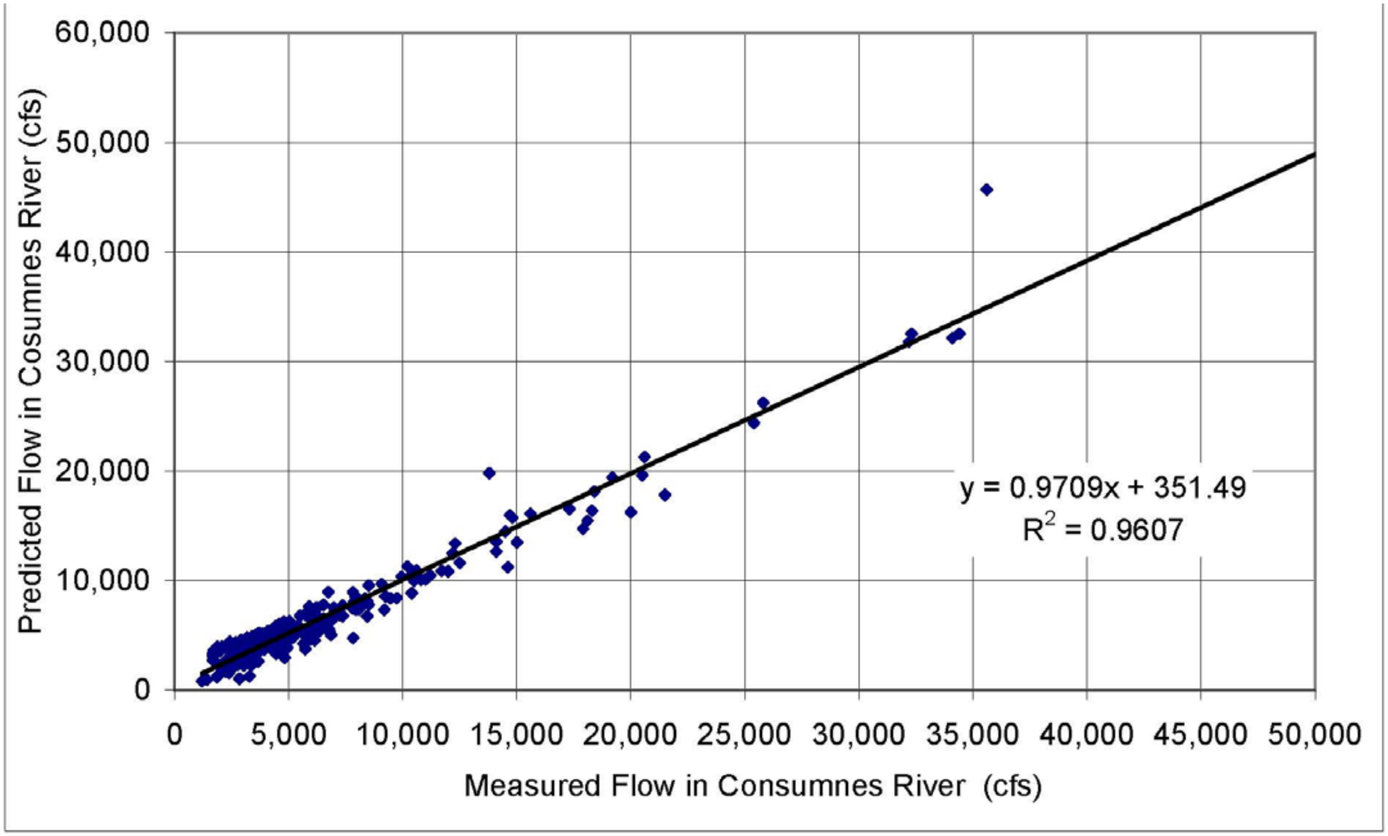


Figure 4-9 Comparison between Predicted and Measured Flows in the Cosumnes River

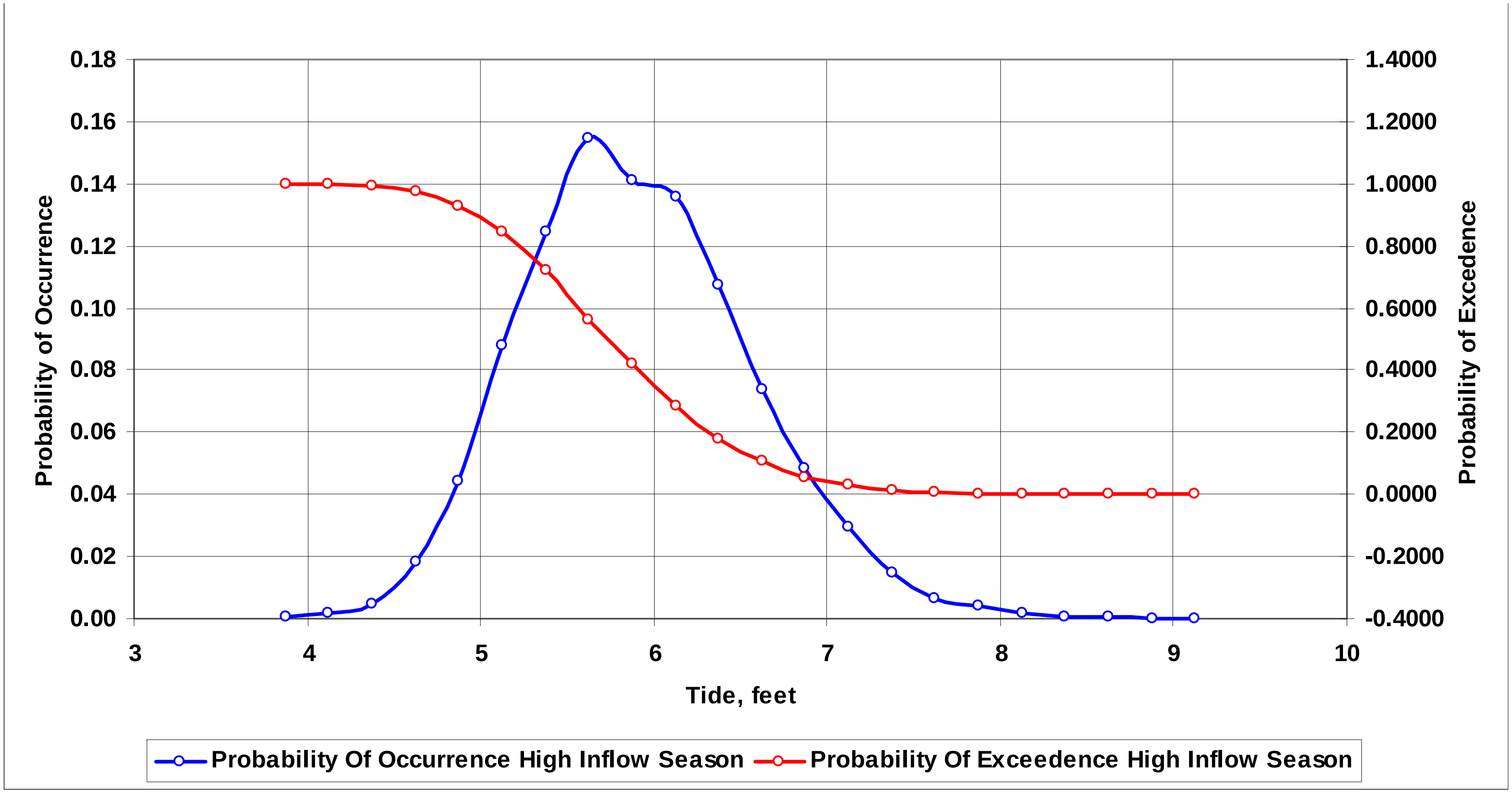
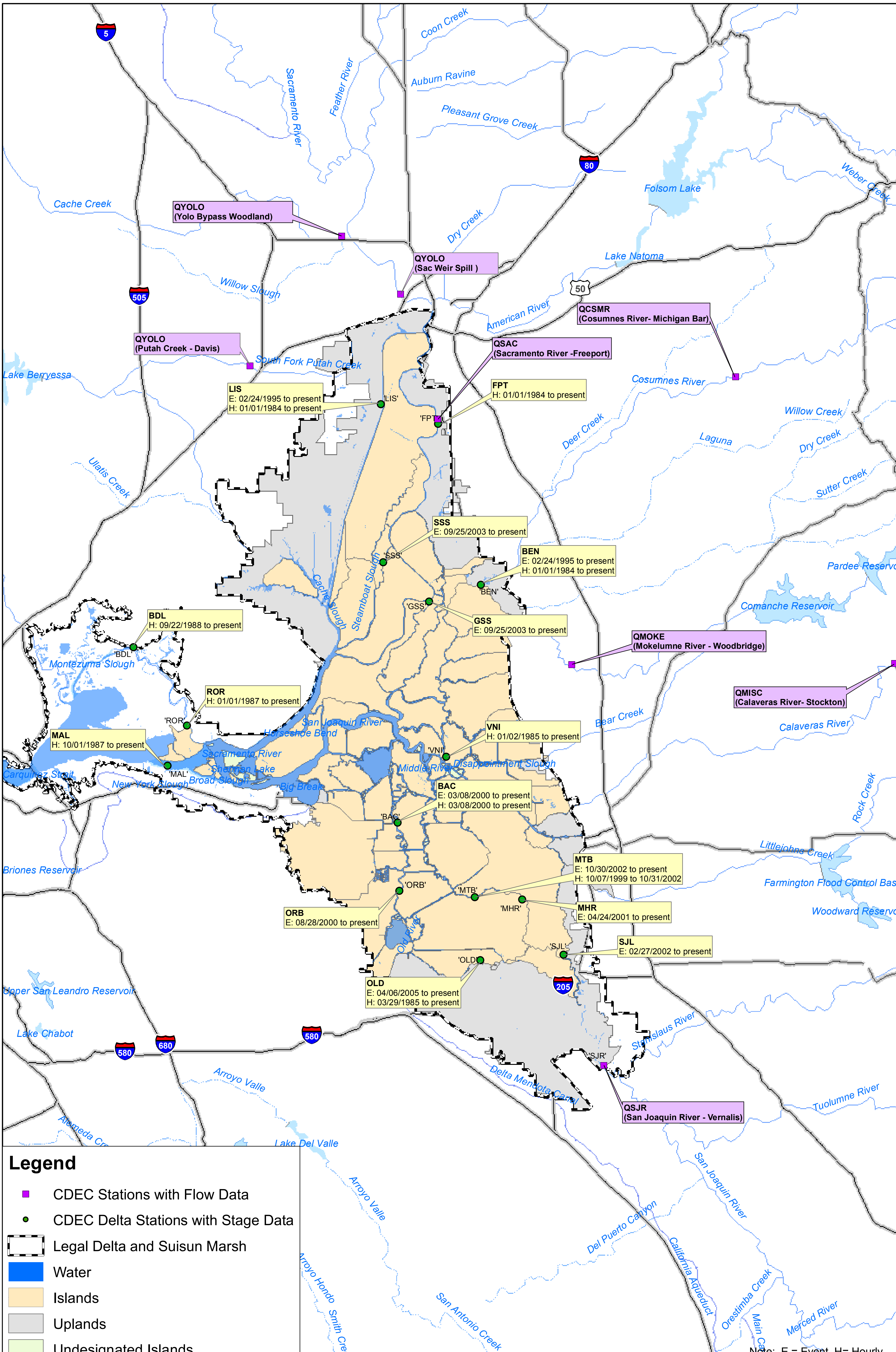


Figure 5-1 San Francisco Tides, High Inflow Season



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URS	DRMS 26815431	Stations Used for Regression Analyses	Figure 5-2

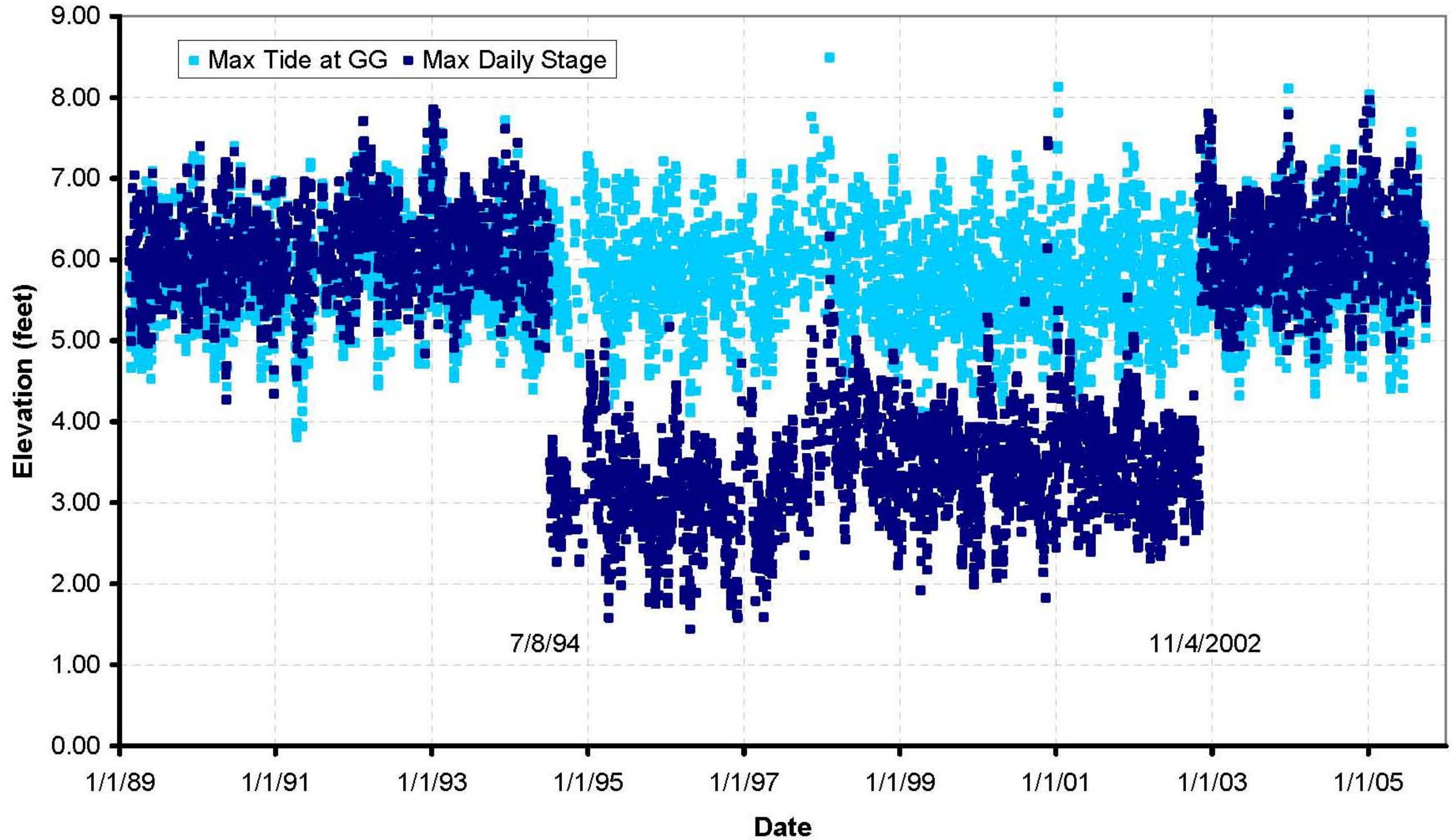

Figure 5-3 Stage Record for Roaring River (ROR) Gauging Station

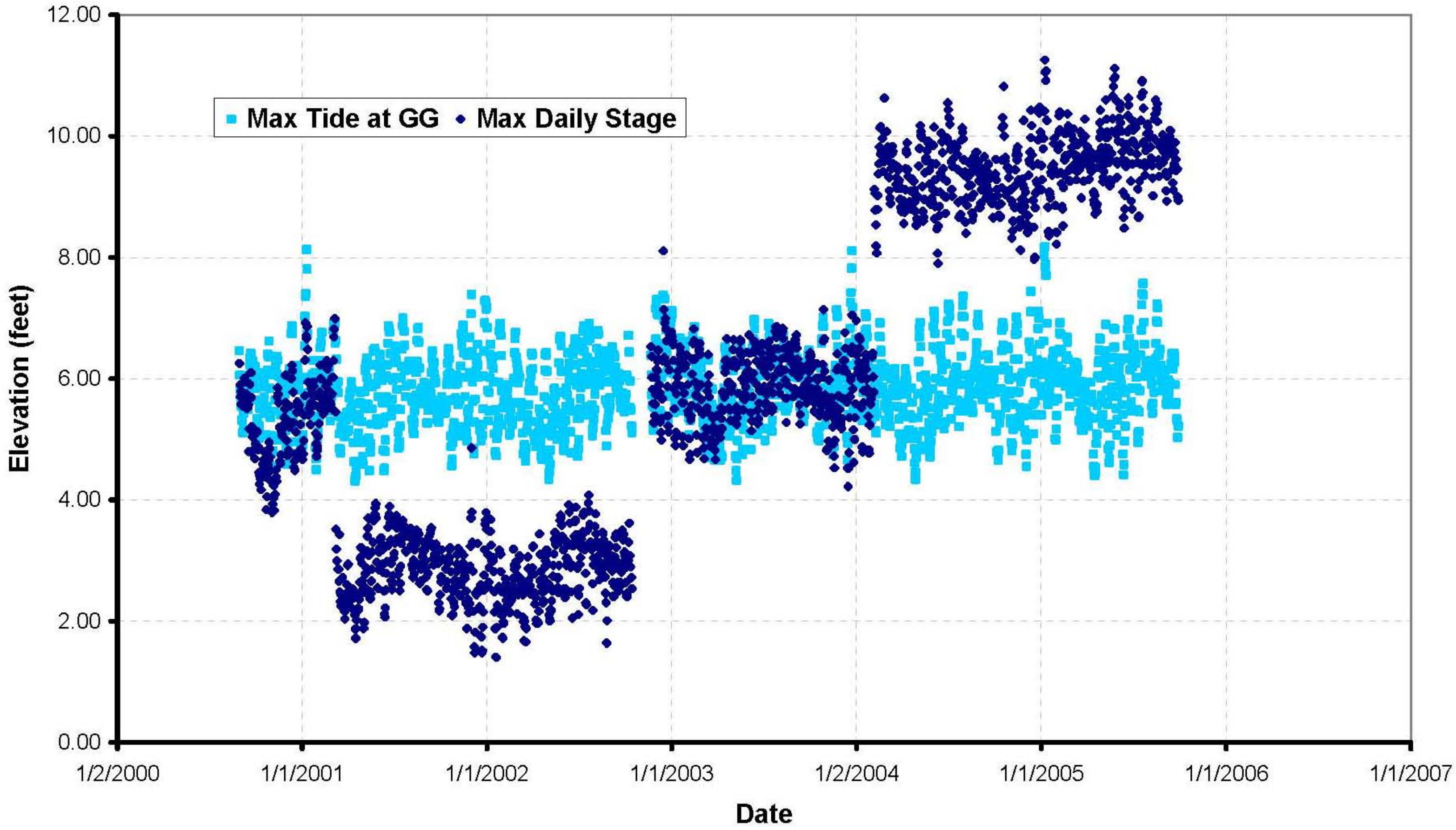

Figure 5-4 Stage Record for Old River at Byron (ORB) Gauging Station

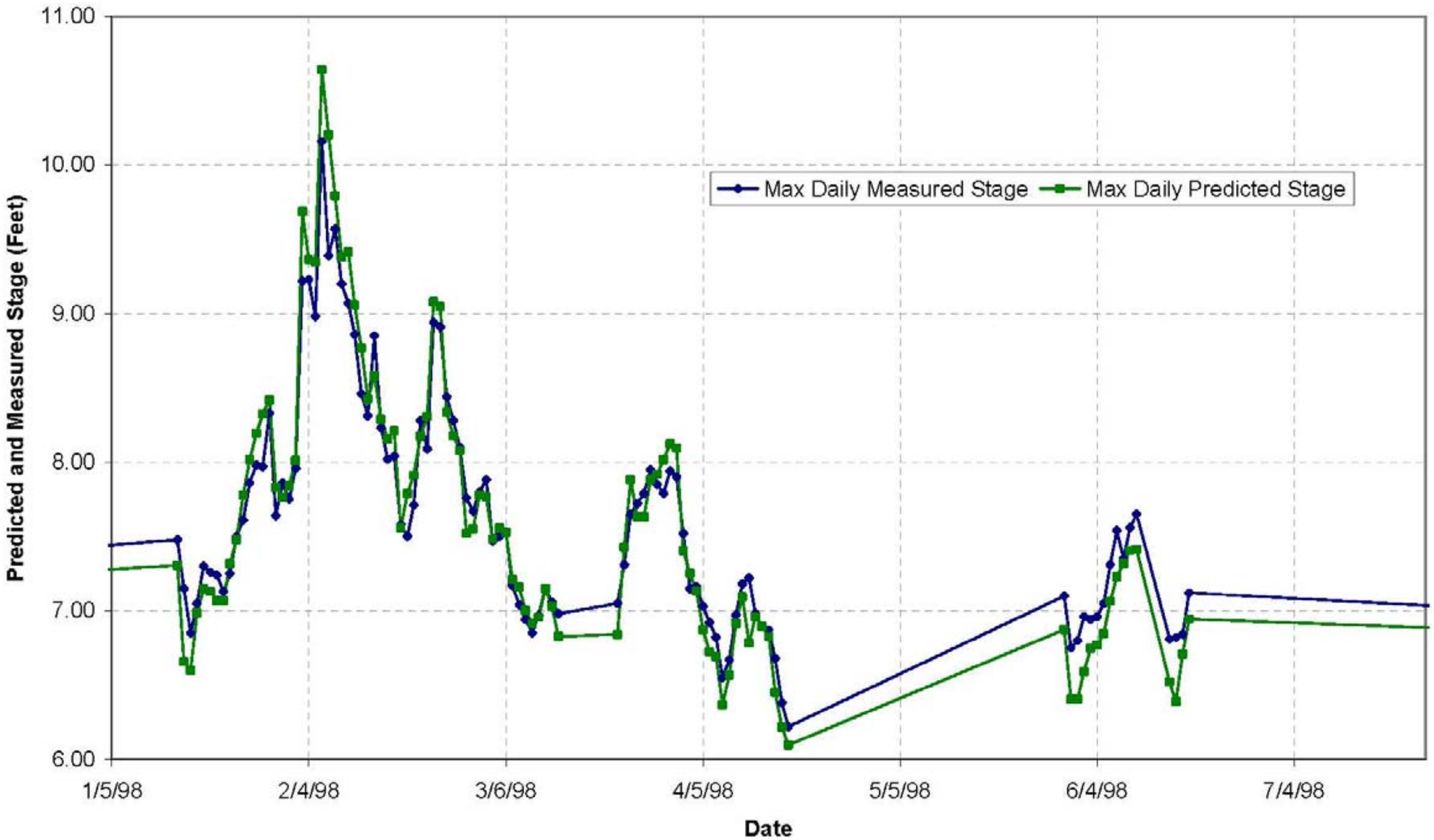

Figure 5-5 Comparison between Measured and Predicted Stage for Venice Island (VNI) for the period between January 5, 1998, and July 6, 1998, for flows above 57,000 cfs.

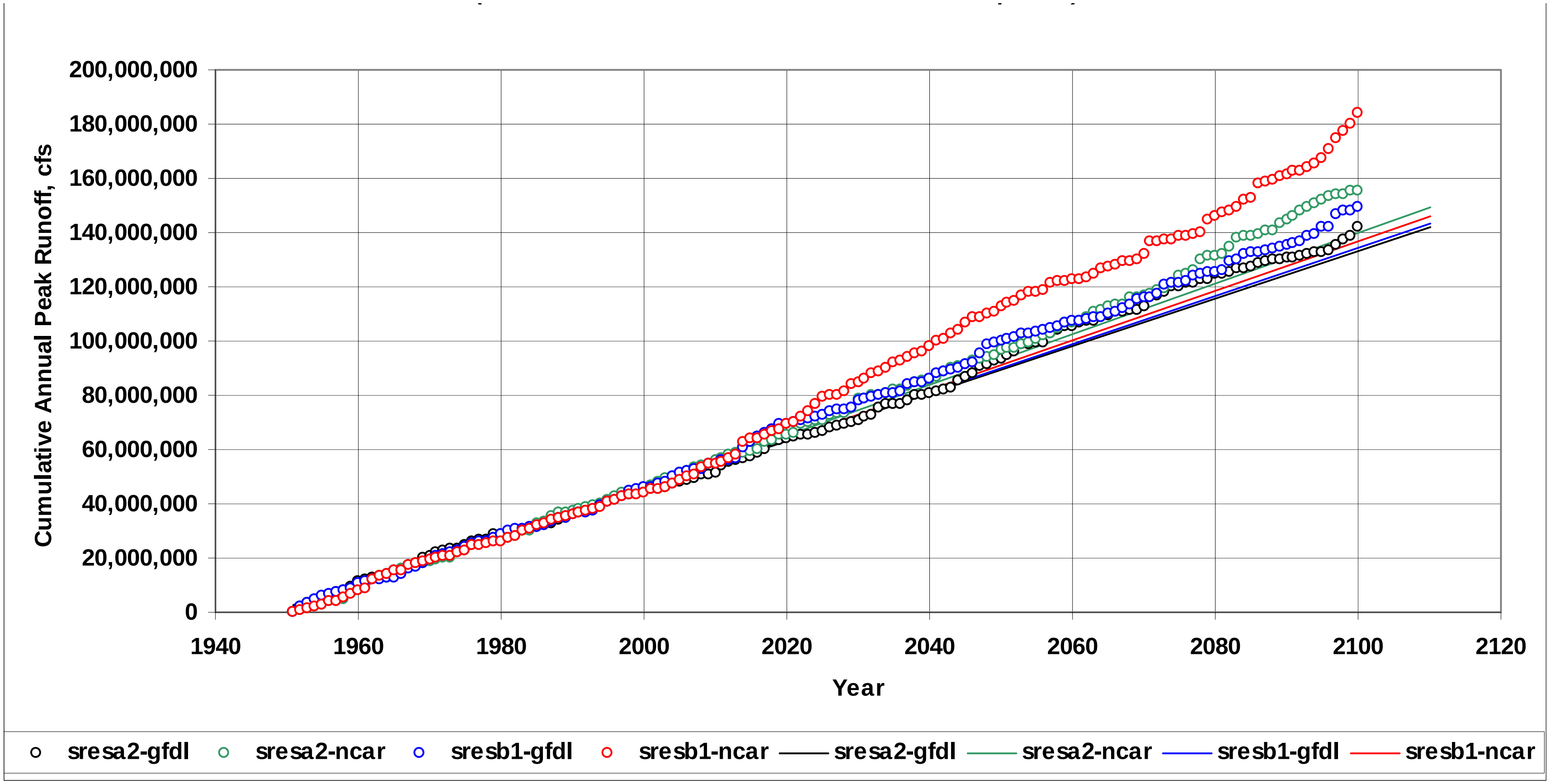

Figure 6-1 Cumulative Annual Peaks vs. Time

(Note: trend lines are trends for the 1951-2001 period)

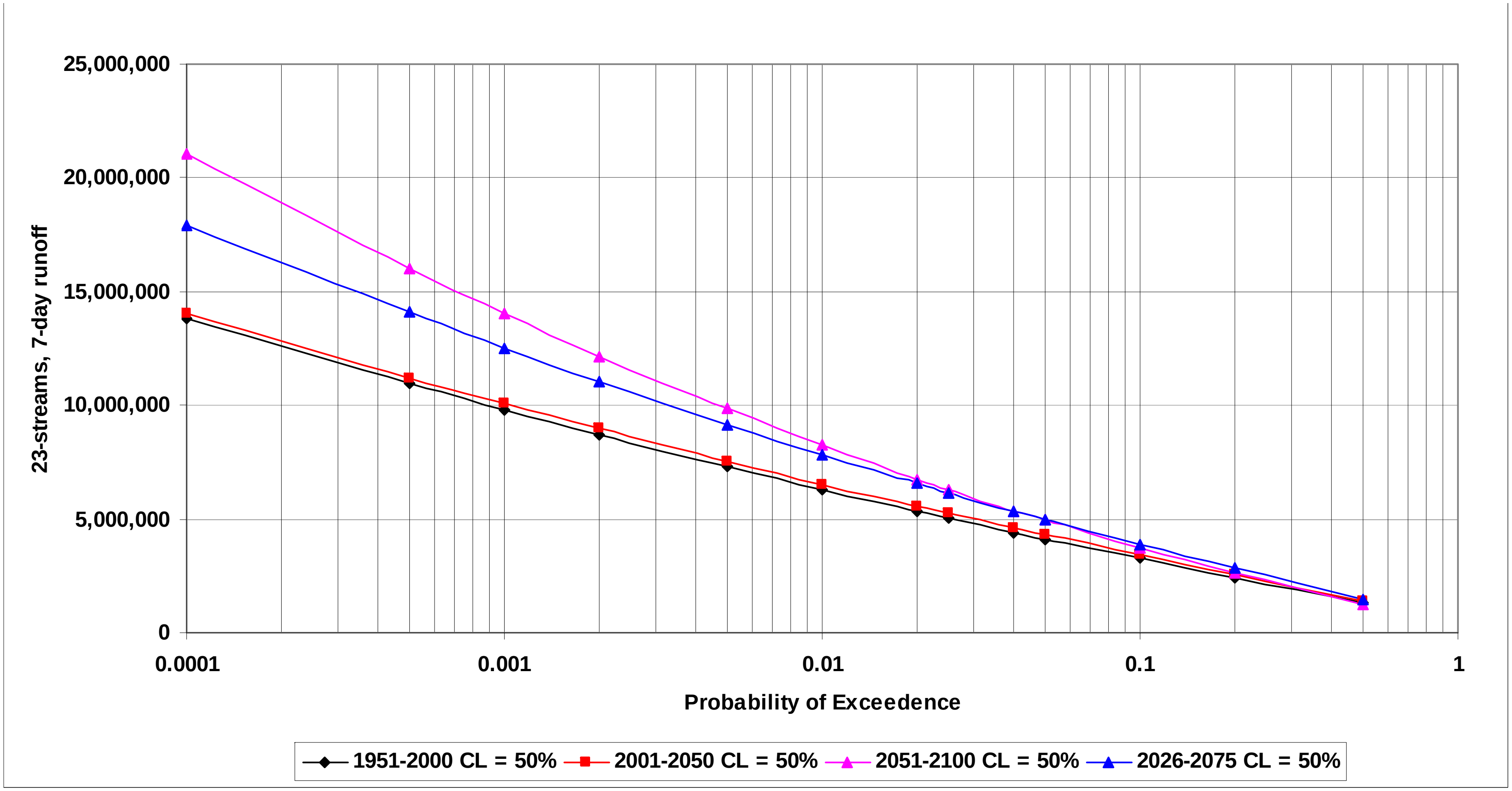

Figure 6-2 Log Pearson Type III, sresa2-gfdl, 50% Confidence Limit

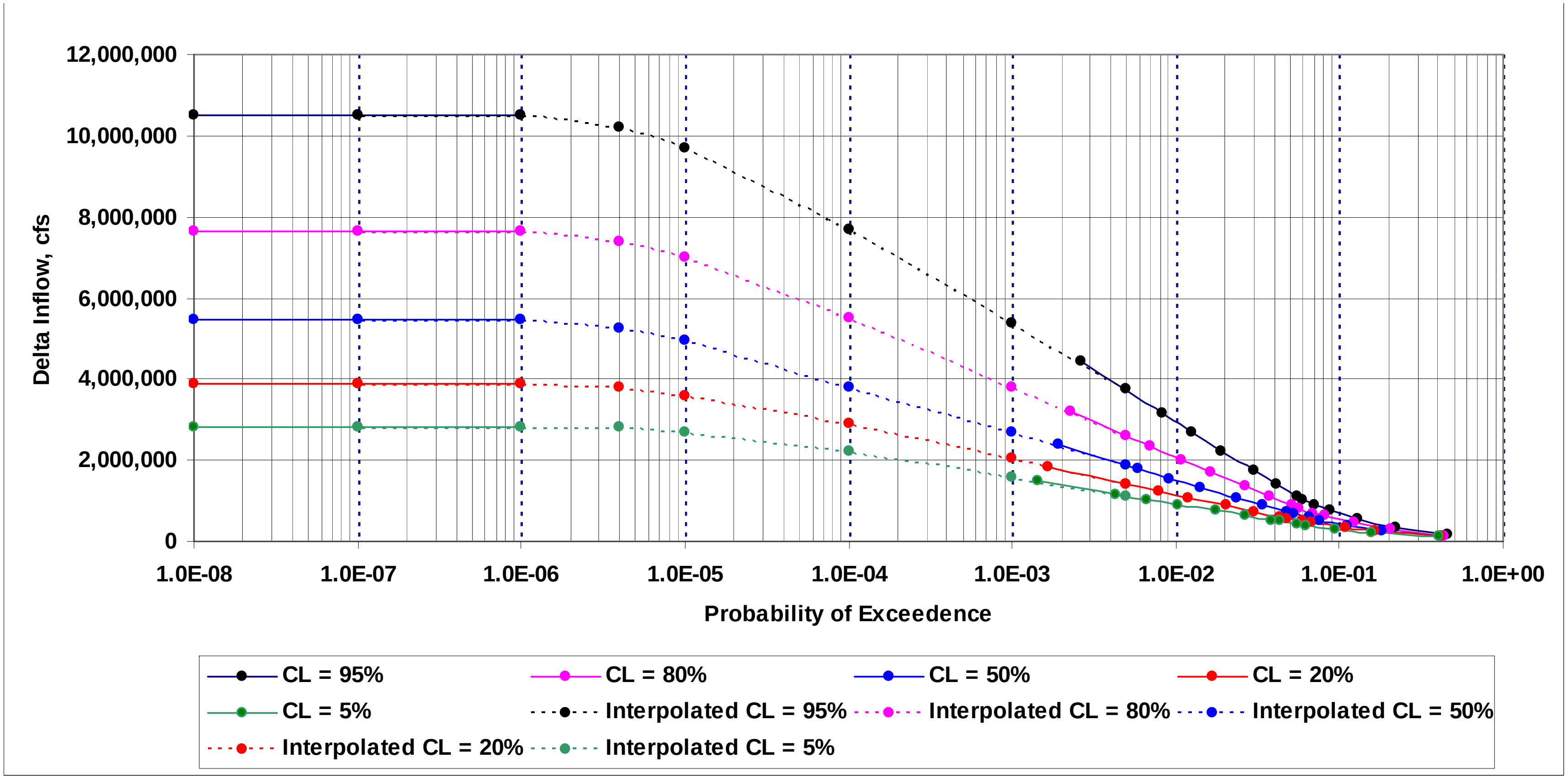

Figure 6-3 Delta Inflow vs. Probability of Exceedance, Sresa2-gfdl, Year 2100

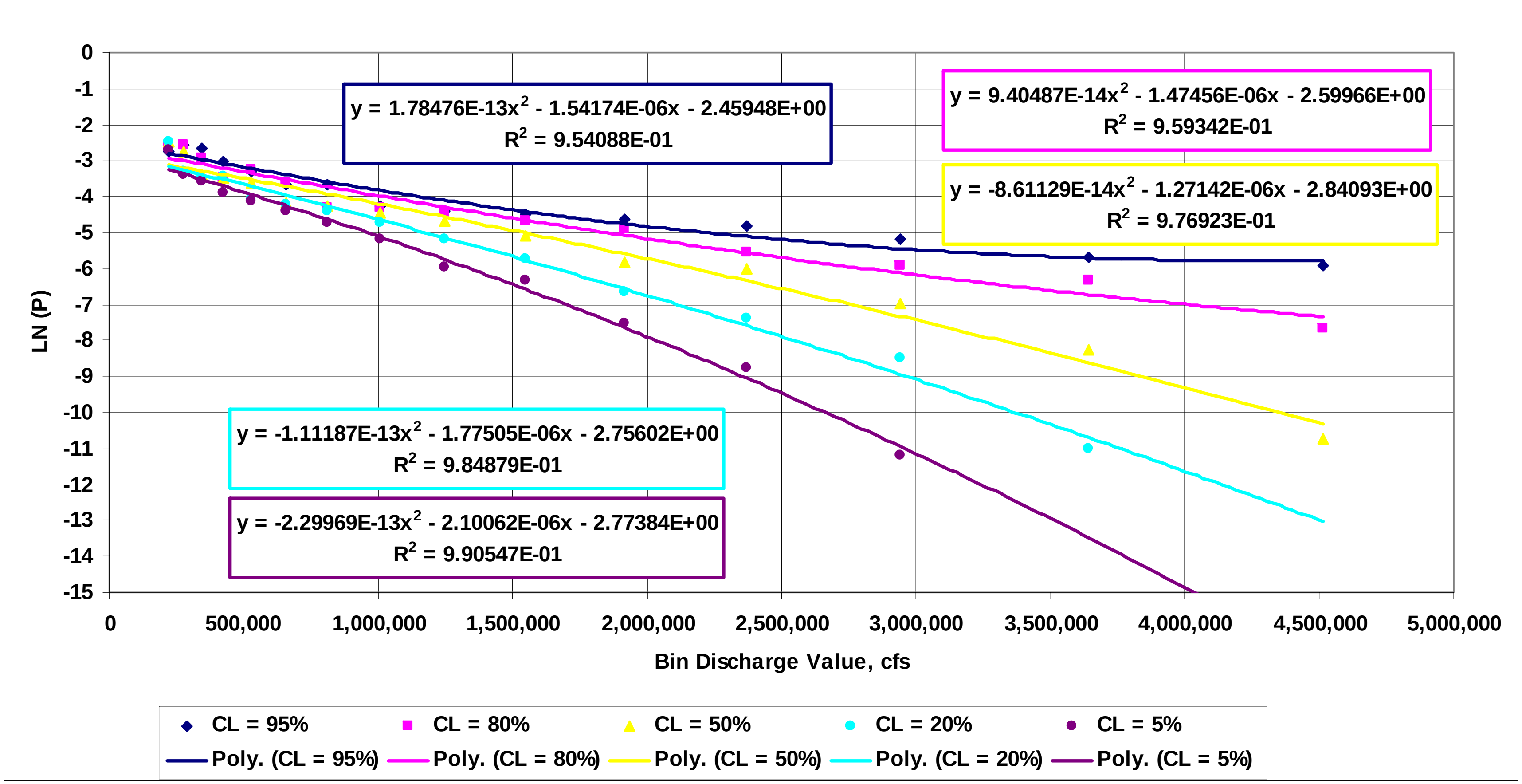

Figure 6-4 LN (Annual Probability), Year 2100, Sresa2-gfdl

Appendix A
Results from Evaluation of Flood Stage Equations

Table A-1
Summary of Comparison Between Observed and Predicted Annual Peak Water Levels

Station Name	Station Identifier	Mean Error (feet)	Standard Deviation of Error (feet)	RMS Error (feet)
San Joaquin River at Antioch	ANH	0.0	0.2	0.23
Bacon Island at Old River	BAC	-0.05	0.39	0.34
Beldon Landing	BDL	-0.02	0.31	0.29
Benson's Ferry	BEN	0.37	1.55	1.54
Sacramento River at Freeport	FPL	0.25	0.71	0.73
Sacramento River at I Street Bridge	IST	0.30	0.51	0.56
Liberty Island - RD2068	LIR	-1.10	0.77	1.32
Yolo Bypass at Lisbon	LIS	0.16	0.83	0.80
Sacramento River at Mallard Island	MAL	0.04	0.20	0.19
Middle River At Howard Road Bridge	MHR	0.01	0.27	0.23
San Joaquin River At Mossdale Bridge	MSD	-0.37	0.60	0.66
Middle River At Tracy Blvd	MTB	0.07	0.24	0.22
Old River At Head	OH1	-0.47	0.83	0.89
Old River Near Tracy	OLD	-0.09	0.16	0.16
Old River At Byron	ORB	0.10	0.25	0.24
Roaring River	ROR	-0.05	0.35	0.34
Rough And Ready Island	RRI	0.00	0.20	0.17
San Joaquin R Blw Old R Near Lathrop	SJL	-0.12	0.11	0.15
Venice Island	VNI	0.06	0.34	0.33

Table A-2 Annual Peak Water Levels

Station	Year	Max Of Adjusted Max Daily	Max Of Predicted Daily	Predicted - Adjusted	Squared Error
ANH					
	1984	7.1	7.1	-0.1	0.0038
	1986	8.4	8.4	0.0	0.0009
	1989	6.2	6.4	0.2	0.0342
	1992	6.9	6.9	0.0	0.0002
	1993	7.3	7.1	-0.2	0.0437
	1995	8.1	7.7	-0.4	0.1590
	1996	7.3	7.1	-0.1	0.0151
	1997	7.8	8.2	0.4	0.1408
	1998	8.8	9.0	0.3	0.0752
	1999	6.4	6.5	0.0	0.0023
	2000	7.1	7.2	0.0	0.0009
	2001	6.1	6.3	0.2	0.0450
	2002	6.9	6.9	0.0	0.0004
	2003	6.4	6.8	0.4	0.1829
	2004	6.8	6.5	-0.3	0.0751
			Mean	0.0	0.05
			Standard Deviation	0.2	0.06
			RMS		0.23
BAC					
	2002	8.50	7.96	-0.54	0.2955
	2003	7.80	7.89	0.09	0.0090
	2004	7.62	8.00	0.38	0.1470
	2005	7.95	7.83	-0.12	0.0137
			Mean	-0.05	0.12
			Standard Dev.	0.39	0.14
			RMS		0.341
BDL					
	1998	7.06	7.40	0.34	0.11
	1999	7.16	7.31	0.15	0.02
	2000	8.09	7.95	-0.15	0.02
	2001	7.33	7.07	-0.26	0.07
	2002	7.71	7.59	-0.12	0.01
	2003	7.22	7.52	0.30	0.09
	2004	7.57	7.01	-0.56	0.31
	2005	7.39	7.52	0.13	0.02
			Mean	-0.02	0.08

Table A-2 Annual Peak Water Levels

Station	Year	Max Of Adjusted Max Daily	Max Of Predicted Daily	Predicted - Adjusted	Squared Error
			Standard Dev.	0.31	0.10
			RMS		0.29
BEN					
	1984	11.95	13.75	1.80	3.22
	1986	13.68	16.73	3.05	9.28
	1989	10.68	9.44	-1.24	1.53
	1993	13.19	12.56	-0.63	0.39
	1995	17.51	18.80	1.29	1.65
	1996	14.88	17.92	3.04	9.25
	1997	8.58	8.50	-0.08	0.01
	1998	13.82	14.96	1.14	1.30
	1999	15.23	16.67	1.44	2.09
	2000	15.14	15.08	-0.06	0.00
	2001	7.56	7.42	-0.14	0.02
	2002	10.57	9.47	-1.10	1.22
	2003	7.57	7.86	0.29	0.08
	2004	11.80	10.68	-1.12	1.24
	2005	13.90	11.80	-2.10	4.40
			Mean	0.37	2.38
			Standard Dev.	1.55	3.06
			RMS		1.54
DLC					
	2004	6.12	6.32	0.20	0.04
	2005	11.08	7.27	-3.82	14.57
FPT					
	1984	21.23	20.80	-0.43	0.19
	1986	27.46	28.64	1.18	1.39
	1989	18.78	17.88	-0.90	0.80
	1992	12.64	13.52	0.88	0.77
	1993	20.02	20.25	0.23	0.05
	1995	24.24	24.54	0.30	0.09
	1996	23.36	23.43	0.07	0.01
	1997	26.30	28.05	1.75	3.08
	1998	23.43	23.02	-0.41	0.17
	1999	21.60	20.92	-0.68	0.46
	2000	21.70	21.43	-0.27	0.08
	2001	12.35	13.29	0.94	0.88

Table A-2 Annual Peak Water Levels

Station	Year	Max Of Adjusted Max Daily	Max Of Predicted Daily	Predicted - Adjusted	Squared Error
	2002	16.80	17.24	0.44	0.20
	2003	16.81	16.92	0.11	0.01
	2004	19.06	19.45	0.39	0.15
	2005	14.66	15.02	0.36	0.13
			Mean	0.25	0.53
			Standard Dev.	0.71	0.79
			RMS		0.73
GCT					
	Not Available				
GSS					
	2004	12.30	12.24	-0.06	
	2005	12.86	12.60	-0.26	
IST					
	1999	27.78	27.43	-0.35	0.12
	2000	27.86	27.92	0.06	0.00
	2001	15.94	17.02	1.08	1.17
	2002	21.45	22.08	0.63	0.39
	2003	21.57	21.56	-0.01	0.00
	2004	24.47	24.88	0.41	0.17
			Mean	0.30	0.31
			Standard Dev.	0.51	0.45
			RMS		0.56
LIR					
	1998	9.09	8.48	-0.61	0.37
	1999	7.34	6.50	-0.84	0.70
	2000	8.55	6.78	-1.77	3.14
	2001	3.93	3.94	0.01	0.00
	2002	7.64	5.33	-2.31	5.35
	2003	5.2	5.07	-0.13	0.02
	2004	7.78	6.46	-1.32	1.75
	2005	9.11	7.62	-1.49	2.23
	2006	10.27	8.80	-1.47	2.17
			Mean	-1.10	1.75
			Standard Dev.	0.77	1.75
			RMS		1.32

Table A-2 Annual Peak Water Levels

Station	Year	Max Of Adjusted Max Daily	Max Of Predicted Daily	Predicted - Adjusted	Squared Error
LIS					
	1984	20.88	20.46	-0.42	0.18
	1986	27.53	29.05	1.52	2.31
	1993	18.19	16.97	-1.22	1.48
	1995	23.81	23.81	0.00	0.00
	1996	19.97	20.42	0.45	0.20
	1997	27.18	28.39	1.21	1.47
	1998	23.32	23.34	0.02	0.00
	1999	17.24	16.95	-0.29	0.08
	2000	18.36	18.50	0.14	0.02
			Mean	0.16	0.64
			Standard Dev.	0.83	0.87
			RMS		0.80
MAL					
	1989	6.30	6.55	0.24	0.06
	1993	7.34	7.27	-0.07	0.00
	1995	7.85	7.73	-0.12	0.02
	1996	7.41	7.30	-0.11	0.01
	1997	7.81	7.99	0.17	0.03
	1998	8.82	9.13	0.31	0.10
	1999	6.66	6.64	-0.02	0.00
	2000	7.29	7.33	0.04	0.00
	2001	6.33	6.51	0.17	0.03
	2002	7.15	7.11	-0.04	0.00
	2003	6.70	7.03	0.32	0.10
	2004	6.93	6.57	-0.36	0.13
	2005	6.96	6.88	-0.08	0.01
			Mean	0.04	0.04
			Standard Dev.	0.20	0.04
			RMS		0.19
MHR					
	2002	7.92	7.62	-0.30	0.09
	2003	7.33	7.64	0.31	0.09
	2004	7.79	7.92	0.13	0.02

Table A-2 Annual Peak Water Levels

Station	Year	Max Of Adjusted Max Daily	Max Of Predicted Daily	Predicted - Adjusted	Squared Error
	2005	8.50	8.39	-0.11	0.01
			Mean	0.01	0.05
			Standard Dev.	0.27	0.04
			RMS		0.23
MRZ					
	Not Available				
MSD					
	2000	11.74	11.32	-0.42	0.18
	2001	5.71	5.46	-0.25	0.06
	2002	5.53	5.55	0.02	0.00
	2003	5.62	4.25	-1.37	1.88
	2004	5.39	5.56	0.17	0.03
			Mean	-0.37	0.43
			Standard Dev.	0.60	0.81
			RMS		0.66
MTB					
	2000	8.02	8.26	0.24	0.06
	2002	6.61	6.67	0.06	0.00
	2003	7.03	7.38	0.35	0.12
	2004	7.46	7.22	-0.24	0.06
	2005	7.87	7.80	-0.07	0.01
			Mean	0.07	0.05
			Standard Dev.	0.24	0.05
			RMS		0.22
OBD					
	Not Available				
OH1					
	2000	10.96	8.83	-2.13	4.55
	2001	4.75	4.63	-0.12	0.01
	2002	4.87	4.68	-0.19	0.04
	2003	4.29	4.22	-0.07	0.00
	2004	4.78	4.81	0.03	0.00
	2005	8.57	8.25	-0.32	0.10
			Mean	-0.47	0.79
			Standard Dev.	0.83	1.85

Table A-2 Annual Peak Water Levels

Station	Year	Max Of Adjusted Max Daily	Max Of Predicted Daily	Predicted - Adjusted	Squared Error
			RMS		0.89
OLD					
	2002	6.94	6.79	-0.15	0.02
	2003	6.66	6.55	-0.11	0.01
	2004	7.01	7.14	0.13	0.02
	2005	8.17	7.93	-0.24	0.06
			Mean	-0.09	0.03
			Standard Dev.	0.16	0.02
			RMS		0.16
ORB					
	2001	6.52	6.77	0.25	0.06
	2002	7.14	7.12	-0.02	0.00
	2003	6.77	7.16	0.39	0.15
	2004	7.63	7.75	0.12	0.01
	2005	8.12	7.87	-0.25	0.06
			Mean	0.10	0.06
			Standard Dev.	0.25	0.06
			RMS		0.24
ROR					
	1993	7.57	7.39	-0.18	0.03
	1995	7.73	7.99	0.27	0.07
	1996	7.48	7.50	0.03	0.00
	1997	7.13	7.40	0.27	0.07
	1998	9.04	9.48	0.44	0.20
	1999	7.06	6.52	-0.53	0.28
	2000	8.05	7.59	-0.46	0.21
	2002	7.17	6.67	-0.50	0.25
	2003	7.04	7.35	0.31	0.09
	2004	7.13	6.91	-0.22	0.05
	2005	7.07	7.09	0.02	0.00
			Mean	-0.05	0.11
			Standard Dev.	0.35	0.10
			RMS		0.34

Table A-2 Annual Peak Water Levels

Station	Year	Max Of Adjusted Max Daily	Max Of Predicted Daily	Predicted - Adjusted	Squared Error
RRI					
	2002	7.55	7.41	-0.14	0.02
	2003	7.07	7.33	0.26	0.07
	2004	7.23	7.28	0.05	0.00
	2005	7.68	7.53	-0.15	0.02
			Mean	0.00	0.03
			Standard Dev.	0.20	0.03
			RMS		0.17
RSL					
	Not Available				
SDC					
	2004	11.57	11.27	-0.30	
	2005	11.86	11.50	-0.36	
SJG					
	2004	7.41	7.31	-0.10	
	2005	7.95	7.90	-0.05	
SJL					
	2002	7.85	7.81	-0.04	0.00
	2003	7.84	7.65	-0.19	0.04
	2004	7.72	7.72	0.00	0.00
	2005	11.65	11.42	-0.23	0.05
			Mean	-0.12	0.02
			Standard Dev.	0.11	0.03
			RMS		0.15
SJR					
	Not Available				
SDR					
	Not Available				
SRV					
	2006	7.47	7.45	-0.02	

Table A-2 Annual Peak Water Levels

Station	Year	Max Of Adjusted Max Daily	Max Of Predicted Daily	Predicted - Adjusted	Squared Error
SSS					
	2004	13.09	12.98	-0.11	
	2005	13.44	13.02	-0.42	
VNI					
	1986	9.67	9.72	0.05	0.00
	1993	8.02	7.98	-0.04	0.00
	1995	8.72	9.16	0.44	0.19
	1996	8.45	8.31	-0.14	0.02
	1997	8.97	8.86	-0.11	0.01
	1998	10.16	10.65	0.49	0.24
	1999	7.95	7.35	-0.60	0.36
	2000	8.54	8.38	-0.16	0.02
	2002	6.88	7.16	0.28	0.08
	2003	7.23	7.82	0.59	0.35
	2004	7.71	7.49	-0.22	0.05
	2005	7.72	7.84	0.12	0.02
			Mean	0.06	0.11
			Standard Dev.	0.34	0.14
			RMS		0.33